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Distance Education in Respiratory Care

ORIGINAL CONTRIBUTIONS

Attitudes of Practicing Respiratory Therapists Toward Completing a Baccalaureate Degree and Distance Education

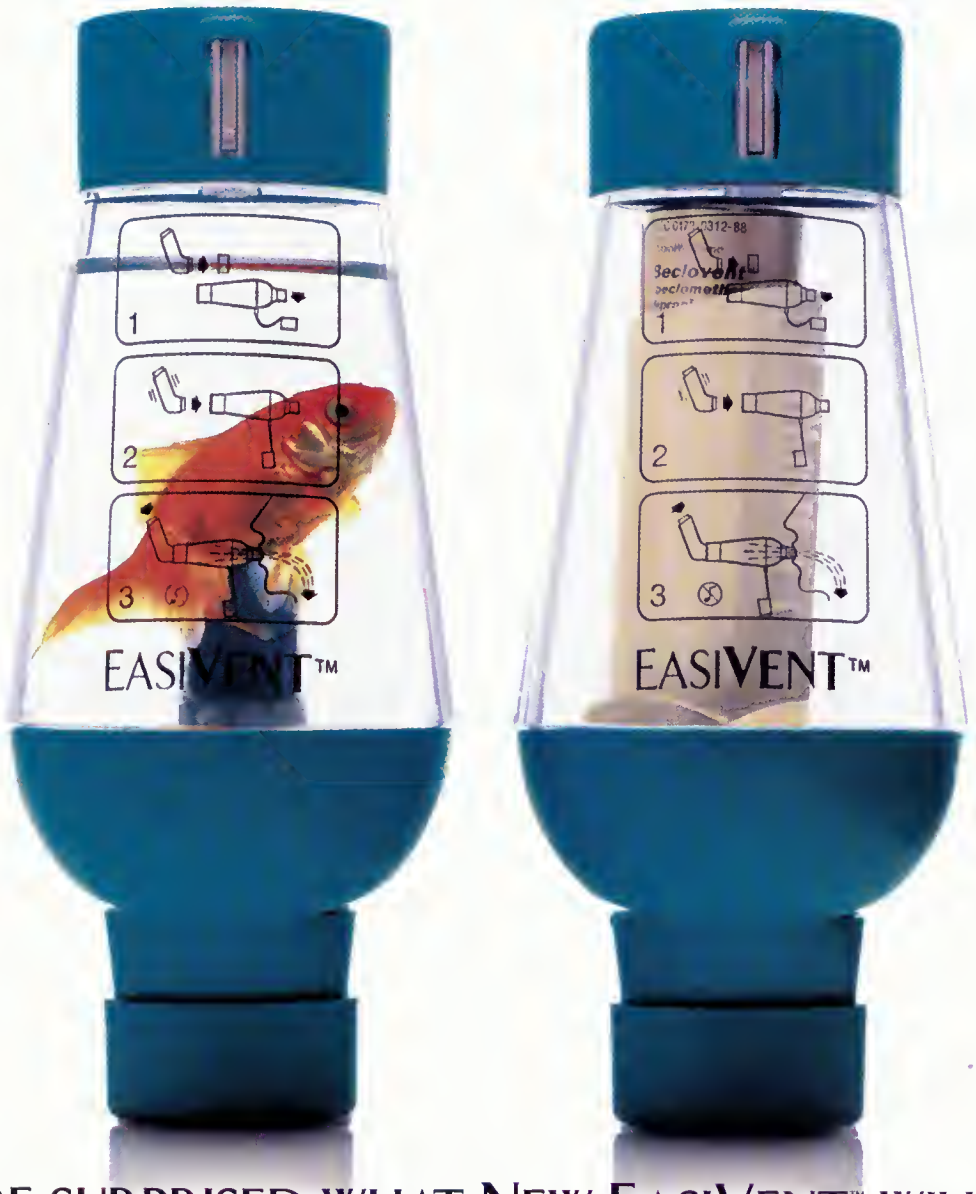
REVIEW ARTICLES

Selection of Devices for Bronchodilator Resuscitation in the Emergency Department

SPECIAL ARTICLES

Diffuse Panbronchiolitis

Withdrawing Mechanical Ventilation



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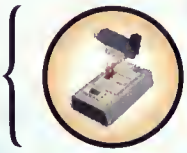

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Reviews the pharmacology section of the revised NAEPP Guidelines. Additionally, the potential hazards and undesirable side effects of commonly prescribed medications will be discussed, with alternative treatment regimens suggested. Featuring William Luskin, MD, and David J. Pierson, MD. 80-min. videotape.

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EDITORIALS

Distance Education in Respiratory Care: Whether We Want It or Not?
by Shelley C Mishoe—Augusta, Georgia **1332**

ORIGINAL CONTRIBUTIONS

Attitudes Among Practicing Respiratory Therapists in a Midwestern State Toward Completing a Baccalaureate Degree and Toward Distance Education
by Ellen A Becker—Brooklyn, New York and Chère C Gibson—Madison, Wisconsin **1337**

REVIEWS, OVERVIEWS, & UPDATES

Bronchodilator Resuscitation in the Emergency Department. Part 1 of 2: Device Selection
by James Fink and Rajiv Dhand—Hines, Illinois **1353**

SPECIAL ARTICLES

Diffuse Panbronchiolitis: Poor Recognition Outside Asia and Implications of Treatment with Erythromycin
by Shinichi Hayashi, Shu Hashimoto, and Takashi Horie—Tokyo, Japan **1375**

Withdrawing Mechanical Ventilation: Conflicts and Consensus
by Mark R Tonelli—Seattle, Washington **1383**

LETTERS

Humidification for Patients with Artificial Airways: More on the HME-Booster
by Georges Gilman—Kapellen, Belgium
Response by Richard D Branson—Cincinnatti, Ohio **1388**

BOOKS, FILMS, TAPES, & SOFTWARE

Pediatric Asthma
reviewed by Anthony G Durmowicz—Denver, Colorado **1390**

Advances in Modeling and Control of Ventilation
reviewed by Michael CK Khoo—Los Angeles, California **1390**

Health Devices Sourcebook 1999 *and* Healthcare Standards 1999 Official Directory
reviewed by Robert L Chatburn—Cleveland, Ohio **1391**

Contagion and Confinement: Controlling Tuberculosis Along the Skid Road
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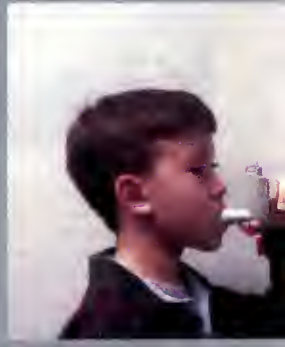

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CONTENTS

CONTINUED...

ALSO IN THIS ISSUE

1399	AARC Membership Application
1320	Abstracts from Other Journals
1408	Advertisers Index & Help Lines
1408	Author Index
1395	Calendar of Events
1401	Call For OPEN FORUM Abstracts
1403	Manuscript Preparation Guide
1397	MedWatch
1396	New Products
1407	Notices

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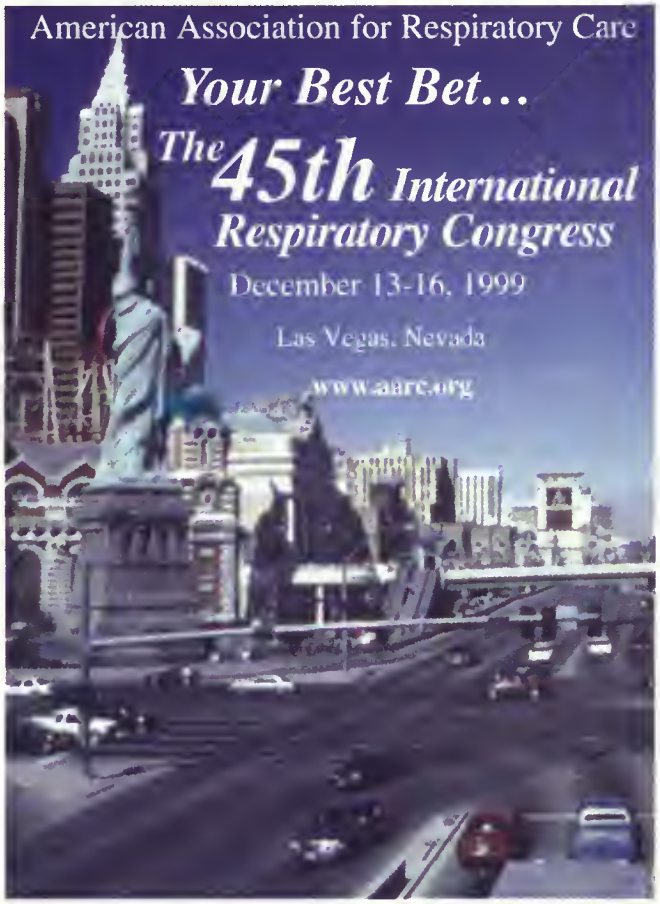

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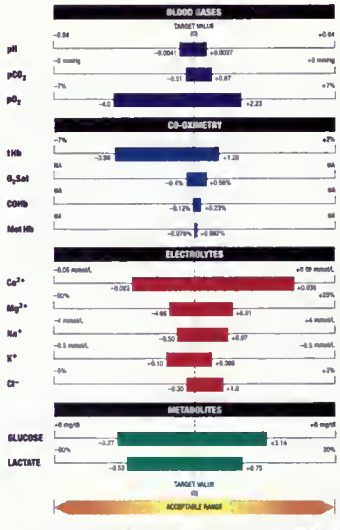

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Providing Better Asthma Care: What Is There Left to Do? Neville RG, Higgins BG. Thorax 1999 Sep;54(9):813–817.

Genetic Epidemiology of Pulmonary Function—Chen Y. Thorax 1999 Sep;54(9):818–824.

The Imposed Work of Breathing Is Less with the Laryngeal Mask Airway Compared with Endotracheal Tubes—Faberowski LW, Banner MJ. Anesth Analg 1999 Sep;89(3):644–646.

Clinical Evidence: Stable Chronic Obstructive Pulmonary Disease—Kerstjens HA. BMJ 1999 Aug 21;319(7208):495–500.

ABC of Intensive Care: Cutting Edge—Singer M, Little R. BMJ 1999 Aug 21;319(7208):501–504.

The DOTs Strategy: More Than Just Watching Patients Take Their Tablets—Fanning A. West J Med 1999 Jul;171(1):4–5.

Clinical Evidence: Tuberculosis—Garner P, Holmes A. West J Med 1999 Jul;171(1):37–40.

Inhalation of Dry Powder Mannitol Improves Clearance of Mucus in Patients with Bronchiectasis—Daviskas E, Anderson SD, Eberl S, Chan HK, Bautovich G. Am J Respir Crit Care Med 1999 Jun;159(6):1843–1848.

Bronchiectasis is a disease characterized by hypersecretion and retention of mucus requiring physical and pharmacologic treatment. Recently we reported that inhalation of dry powder mannitol markedly increases mucociliary clearance (MCC) in asthmatic and in healthy subjects (Daviskas, E., S. D. Anderson, J. D. Brannan, H. K. Chan, S. Eberl, and G. Bautovich. 1997. Inhalation of dry-powder mannitol increases mucociliary clearance. Eur. Respir. J. 10:2449–2454). In this study we investigated the effect of mannitol on MCC in patients with bronchiectasis. Eleven patients 40 to 62 yr of age inhaled mannitol (approximately 300 mg) from a Dinkihaler. MCC was measured over 90 min, in the supine position, on three occasions involving: mannitol or control or baseline, using a radioaerosol technique. On the control day patients reproduced the breathing maneuvers and the number of coughs induced by the mannitol. Mannitol significantly increased MCC over the 75 min from the start of the intervention compared with control and baseline in the whole right lung, central, and intermediate region. Mean (± SEM) clearance with mannitol was 34.0± 5.0% versus 17.4± 3.8% with control and 11.7± 4.4% with baseline in the whole right lung ($p < 0.0001$). The mean number of coughs induced by mannitol was 49± 11. In conclusion, inhalation of dry powder mannitol increased clearance of mucus and thus has the potential to benefit patients with bronchiectasis.

A Novel, Short, and Simple Questionnaire to Measure Health-Related Quality of Life in Patients with Chronic Obstructive Pulmonary Disease—Hajiro T, Nishimura K, Jones PW, Tsukino M, Ikeda A, Koyama H, Izumi T. Am J Respir Crit Care Med 1999 Jun;159(6):1874–1878.

A novel, short, and simple questionnaire, the Airways Questionnaire 20 (AQ20), has been developed to measure and quantify disturbances in the health-related quality of life (HRQoL) of patients with asthma or chronic obstructive pulmonary disease (COPD). The AQ20 has 20 items with yes/no responses, and should take 2 min to complete and score. The purpose of this study was to assess the discriminative properties and responsiveness of the AQ20 in patients with COPD. First, in a cross- sectional study, 165 patients with mild-to-severe COPD (mean age, 69± 7 yr; FEV_1, 40± 16% of predicted) completed the AQ20, the St. George's Respiratory Questionnaire (SGRQ), the Chronic Respiratory Disease Questionnaire (CRQ), pulmonary function tests, a progressive cycle ergometer exercise test, and an assessment of their dyspnea and anxiety. The score distribution of the AQ20 was skewed toward the mild end of the scale, whereas the SGRQ and CRQ showed a normal distribution. The AQ20 showed a moderately strong correlation with the maximal oxygen uptake and the assessment of dyspnea (Spearman's correlation coefficients [rs] = -0.49, -0.60, respectively), but a weak correlation with the FEV_1 (rs = -0.18). Moderate to strong correlations were also recognized between the AQ20 and SGRQ and CRQ (rs = -0.80, -0.72, respectively). Multiple regression analysis revealed that dyspnea and anxiety accounted for 43% of the variance in the AQ20, almost the same as in the SGRQ and CRQ. Second, longitudinal changes over time in the FEV_1, AQ20, SGRQ, and CRQ were examined in 86 patients with newly detected COPD (mean age, 69± 8 yr; FEV_1, 45± 19% of predicted). All three measures showed significant improvements in their scores over a 3-mo period after initiating medical intervention. The change in the AQ20 showed a moderate to strong correlation with each dimension of the SGRQ and CRQ (rs = 0.56, -0.52, respectively), but no significant correlation was noted with the FEV_1. In conclusion, the AQ20 may have discriminative properties and responsiveness that are similar to more complex questionnaires such as the SGRQ and CRQ. Because it is short and can be quickly answered and scored, the AQ20 may be useful in studies with limited time for HRQoL assessments.

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- Postural Drainage Therapy
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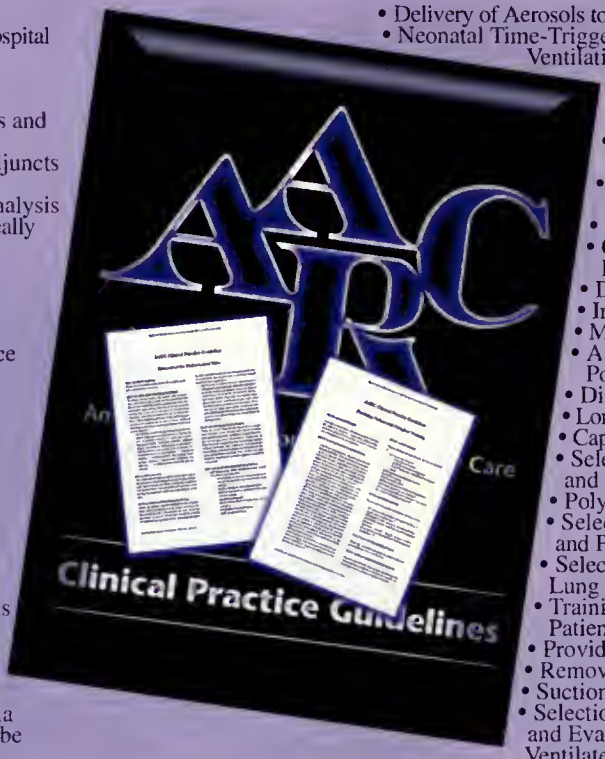

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Severe Accidental Hypothermia: Rewarming Strategy Using a Veno-Venous Bypass System and a Convective Air Warmer—Brauer A, Wrigge H, Kersten J, Rathgeber J, Weyland W, Burchardi H. Intensive Care Med 1999 May; 25(5):520–523.

OBJECTIVE: To study a rewarming strategy for patients with severe accidental hypothermia using a simple veno-venous bypass in combination with a convective air warmer. SETTING: Eighteen beds in a university hospital intensive care unit. PATIENTS: Four adults admitted with a core temperature less than 30 degrees C. Hypothermia was caused by alcoholic intoxication in three patients and by drug overdose in one patient. MEASUREMENTS AND MAIN RESULTS: All patients were rewarmed by a veno-venous bypass and in three cases a convective air warmer was also used. At a bypass flow rate of 100–300 mL/min the mean increase in core temperature was 1.15 degrees C/h (Range: 1.1–1.2 degrees C/h). One patient died 2 days after rewarming as a consequence of a reactivated pancreatitis. The other three patients survived without neurological sequelae. CONCLUSION: This rewarming technique seems safe and effective and allowed the controlled rewarming of our patients who suffered from severe accidental hypothermia.

Bronchopleural Fistula Complicating Group A Beta-Haemolytic Streptococcal Pneumonia: Use of a Fogarty Embolectomy Catheter for Selective Bronchial Blockade—McCormick BA, Wilson IH, Berrisford RG. Intensive Care Med 1999 May;25(5):535–537.

A 36-year-old woman developed severe group A Streptococcal pneumonia, complicated by a bronchopleural fistula, ARDS and multi-organ failure. We describe the use of selective middle lobe bronchus blockade, with a Fogarty embolectomy catheter, to localise and control the air leak. This allowed effective mechanical ventilation and oxygenation on intensive care and during right middle lobectomy. The patient made a prolonged, but full recovery.

Early S_{jvO2} Monitoring in Patients with Severe Brain Trauma—Vigue B, Ract C, Benayed M, Zlotine N, Leblanc PE, Samii K, Bissonnette B. Intensive Care Med 1999 May; 25(5):445–451.

OBJECTIVE: To investigate early cerebral variables after minimal resuscitation and to compare the adequacy of a cerebral perfusion pressure (CPP) guideline above 70 mm Hg, with jugular bulb venous oxygen saturation (S_{jvO2}) monitoring in a patient with traumatic brain injury (TBI). DESIGN: Prospective, observational study. SETTING: Anesthesiological intensive care unit. PATIENTS: 27 TBI patients with a postresuscitation Glasgow Coma Scale score less than 8. INTERVENTION: After initial resuscitation, cerebral monitoring was performed and CPP increased to 70 mm Hg by an increase in mean arterial pressure (MAP) with volume expansion and vasopressors as needed. MEASUREMENTS AND RESULTS: MAP, intracranial pressure (ICP), CPP, and simultaneous arterial and venous blood gases were measured at baseline and after treatment. Before treatment, 37% of patients had an S_{jvO2} below 55%, and S_{jvO2} was significantly correlated with CPP ($r = 0.73$, $p < 0.0001$). After treatment, we observed a significant increase ($p < 0.0001$) in CPP (78±10 vs 53±15 mm Hg), MAP (103±10 vs 79±9 mm Hg) and S_{jvO2} (72±7 vs 56±12), without a significant change in ICP (25±14 vs 25±11 mm Hg). CONCLUSION: The present study shows that early cerebral monitoring with S_{jvO2} is critical to assess cerebral ischemic risk and that MAP monitoring alone is not sensitive enough to determine the state of oxygenation of the brain. S_{jvO2} monitoring permits the early identification of patients with low CPP and high risk of cerebral ischemia. In emergency situations it can be used alone when ICP monitoring is contraindicated or not readily available. How-

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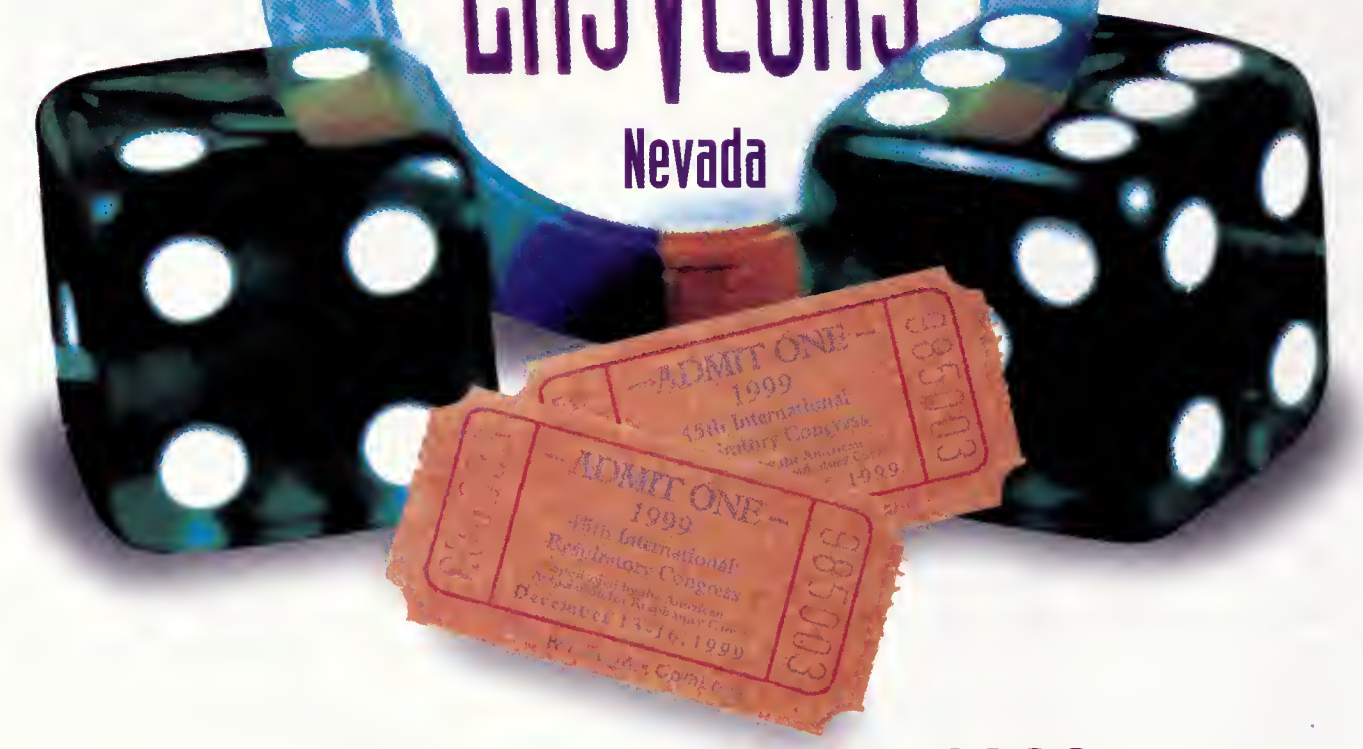

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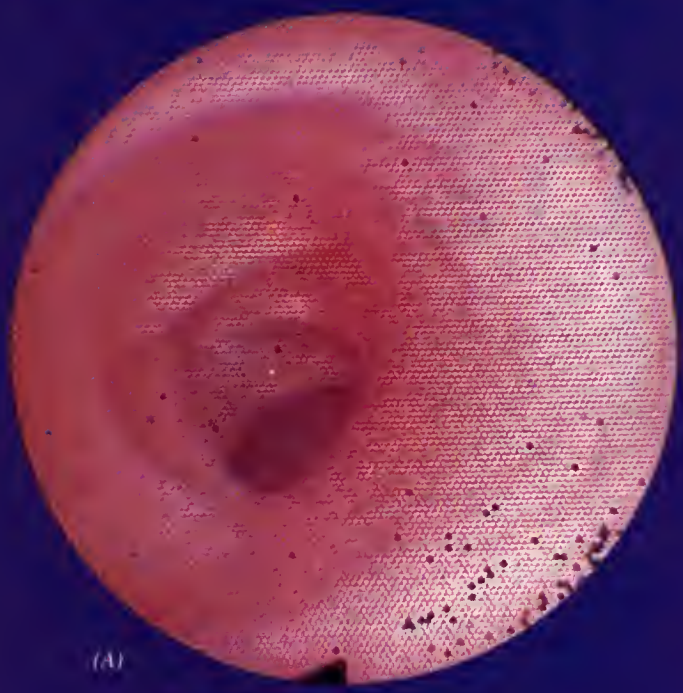

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ever, ICP monitoring gives complementary information necessary to adapt treatment.

Effect of Inspiratory Flow Waveform on Work on Endotracheal Tubes: A Model Analysis—Polese G, D'Angelo E, Rossi A, Milic-Emili J. Intensive Care Med 1999 May;25(5): 503–507.

OBJECTIVE: This model analysis aimed to predict the impact of different inspiratory flow wave-forms, i. e., constant, sinusoidal, and two linearly decreasing flows, on the resistive work (Wres) performed on endotracheal tubes. DESIGN: Model analysis. RESULTS: Model analysis predicts that: (i) minimal Wres is obtained with the constant flow; (ii) for any given tidal volume/inspiratory duration (V_T/T_I, mean inspiratory flow), Wres increases with decreasing tube size; (iii) for any given inspiratory flow waveform, Wres increases with increasing V_T/T_I, being lowest with constant flow. CONCLUSIONS: These findings have major clinical implications: at any given ventilator setting, not only the size of the endotracheal tube but also the inspiratory flow waveform must be taken into account to interpret the values of Wres and hence of the total work of breathing.

Mechanical Ventilation of Patients on Long-Term Oxygen Therapy with Acute Exacerbations of Chronic Obstructive Pulmonary Disease: Prognosis and Cost-Utility Analysis—Anon JM, Garcia de Lorenzo A, Zarazaga A, Gomez-Tello V, Garrido G. Intensive Care Med 1999 May;25(5):452–457.

OBJECTIVE: To analyze the prognosis and costs of mechanical ventilation in patients with exacerbations of chronic obstructive pulmonary disease (COPD) treated with long-term oxygen therapy. DESIGN: A prospective cohort study. Follow-up at 1 and 5 years. Cost utility analysis. SETTING: A medical-surgical intensive care unit (ICU) in a university hospital. PATIENTS: 20 patients with previous COPD treated with long-term oxygen therapy and needing mechanical ventilation due to acute respiratory failure. MEASUREMENTS AND MAIN RESULTS: Mortality in the ICU, in-hospital mortality (ICU plus ward), and mortality at 1 and 5 years, and factors associated with prognosis and cost-utility were assessed. The mean Acute Physiology and Chronic Health Evaluation II score was 20 (median 20 range 12–36). Cumulative mortality was 35% in the ICU, 50% in hospital, 75% at 1 year, and 85% at 5 years. Factors significantly associated with mortality in the ICU were low levels of albumin ($p = 0.05$) and sodium ($p = 0.01$) at admission. Patients who died in hospital and in the first year after discharge had a lower forced expiratory volume in 1 s (FEV_1) than survivors ($p = 0.03$ and $p = 0.05$, respectively). The cost per Quality Adjusted Life Year (QALY) was U.S. $26283 and U.S. $44602 in a "best" (cost/QALY calculated for the life expectancy in Spain) and a "worst case scenario" (cost/QALY calculated for a 68-year life expectancy), respectively. CONCLUSIONS: Applying mechanical ventilation to COPD patients treated with long-term oxygen therapy carries a high mortality and cost. Factors significantly associated with mortality in the ICU were albumin and sodium concentrations and FEV_1 in hospital and in the first year after discharge.

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Partial Liquid Ventilation Combined with Kinetic Therapy in Acute Respiratory Failure in Piglets—Urlesberger B, Zobel G, Dacar D, Rodl S, Trafojer U, Trantina A, Knez J. Intensive Care Med 1999 May;25(5):496–502.

OBJECTIVE: To investigate the effect of the combination of kinetic therapy (KT) with partial liquid ventilation (PLV) on gas exchange, lung mechanics and hemodynamics in acute lung injury (ALI). DESIGN: Prospective, randomized, controlled pilot study. SETTING: University research laboratory. SUBJECTS: Eleven piglets weighing 8.3±0.9 kg. INTERVENTION: ALI was induced by the infusion of oleic acid (0.08 mL/kg) and repeated lung lavages with 0.9% NaCl (20 mL kg^{-1}). Thereafter the animals were randomly assigned either for PLV or a combination of PLV with KT (PLV/KT). The dose of perfluorocarbon administered was 30 mL/kg, evaporative losses were substituted with 5 mL/kg per h. MEASUREMENTS AND MAIN RESULTS: Airway pressures, tidal volumes, dynamic compliance (Cdyn), expiratory airway resistance and arterial blood gases were measured. Hemodynamic monitoring included right atrial, mean pulmonary artery, pulmonary capillary wedge and mean systemic arterial pressures, and continuous flow recording of the pulmonary artery. In both groups the induction of ALI significantly reduced P_{aO_2}/F_{IO_2}, Cdyn and cardiac output, and significantly increased pulmonary artery pressure. After the initiation of PLV there was a significant increase of P_{aO_2}/F_{IO_2}, and Cdyn, and a significant decrease of pulmonary artery pressure in both groups. Except the P_{aCO_2}, which showed significantly lower values in the PLV/KT group, no variables showed any differences between the two groups. CONCLUSION: The additional use of KT did not show beneficial effects on oxygenation and lung mechanics during PLV. However, at constant minute ventilation P_{aCO_2} levels were significantly lower during PLV/KT, indicating some positive influence on the ventilation/perfusion distribution within the lung. Extreme body positions during PLV/KT did not show any significant hemodynamic side effects.

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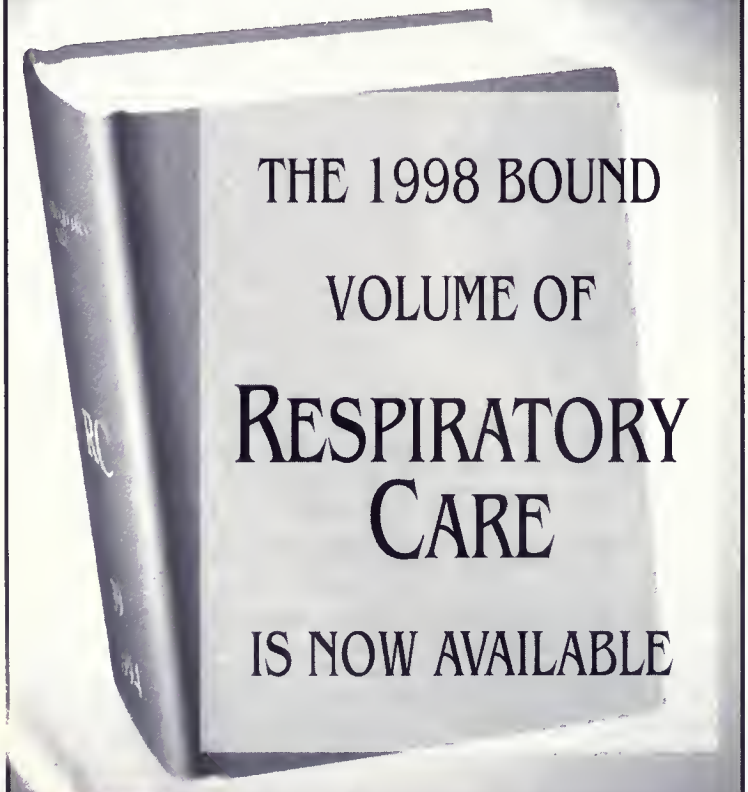

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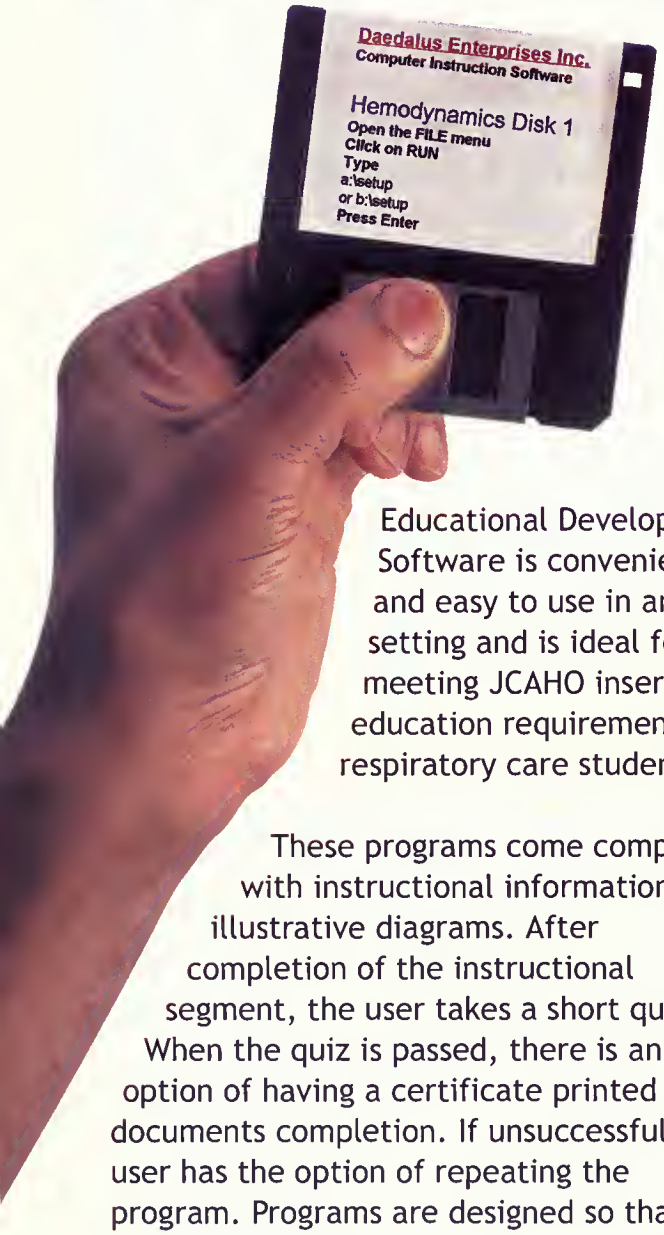

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Item SP18

Muscular Dystrophy Simulation
This is a simulation of a 10-year-old with diagnosed muscular dystrophy who is entering the ER with respiratory distress. The simulation asks for patient assessment and initial therapy recommendations. Diagnostic tests are then presented to evaluate the degree of muscle involvement, and the user is required to recommend further therapy based on the results of these tests. As the simulation progresses, IPPB is required and the user is asked to provide instructions to the patient on IPPB treatment. CPT is also involved, with the correct positioning of the patient required.
Item SP19

Chest Trauma II Simulation
Involves a motor-vehicle-accident patient with multiple trauma. Initial assessment followed by oxygen therapy occurs in the ER, followed by further assessment leading to intubation and placement on a mechanical ventilator. Based on blood gas results, several ventilator changes are made. The patient suffers a pneumothorax while on the ventilator, and the user is required to assess and recommend treatment for the condition. In addition, the simulation includes measurement and clinical application of compliance.
Item SP110

Neonate II Simulation
Begins with the assessment of a neonate delivered by C-section who is receiving oxygen in an incubator. Based on the assessment, the infant is intubated and placed on CPAP; but problems occur, requiring extubation and bag ventilation. After reintubation, the CPAP level is changed based on ABG results, and the user is required to evaluate the infant for extubation. In the simulation, the patient then fails the procedure and the user must evaluate the patient to determine the cause of the problem.
Item SP111

Cystic Fibrosis Simulation
This simulation presents a 13-year-old patient with cystic fibrosis in the outpatient clinic. The initial task is to perform a pulmonary assessment, after which a decision must be made concerning action to be taken based on the assessment. Following obtainment of additional diagnostic information, the patient is admitted; but the user is asked to set up a regimen of home care therapy, including recommendations about chest physiotherapy, oxygen therapy, aerosol therapy, and disinfecting home care equipment. The child is admitted two weeks later for further assessment and recommendations regarding treatment.
Item SP112

Pulmonary Rehabilitation Simulation
Presents a 65-year-old woman admitted to the ER with progressive shortness of breath over two days. Initial assessment reveals evidence of chronic lung disease, an ABG sample is obtained, and oxygen therapy is initiated. Further evaluation, including lab values, is initiated following the initial therapy. Based on the lab values, an SVN with bronchodilator and chest physiotherapy is begun. During the administration of CPT, the patient becomes breathless while making vigorous inspiratory effort. CPR is initiated, resulting in a successful resuscitation. Three days later, the user is asked to evaluate and classify the severity of the patient's lung disease and to develop a home care plan.
Item SP113

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Distance Education in Respiratory Care: Whether We Want It or Not?

Distance education, particularly the current emphasis on instructional technology, is being examined, utilized, and debated throughout the world at an increasing rate. There are mixed views toward distance education within the respiratory care profession and across disciplines. Like many educators today, my faculty and I are experiencing increased pressure to offer various types of programs to learners at a distance. There are many questions whenever an educational innovation such as distance education is introduced:

- Is it as good as traditional education?
- Do students receive a comparable learning experience?
- What does it cost?
- What variables determine instructional effectiveness?
- What are the outcomes?
- Which learners can benefit?
- Does the learning transfer to the work place?
- Do instructors have to teach differently?

See The Original Study On Page 1337

I must admit that I agreed to write this editorial because I welcomed the opportunity to further examine my own multiple perspectives. I can appreciate the many advantages and also the limitations of distance education.

Distance education (also referred to as distance learning) has been defined as "formal instruction in which a majority of the teaching function occurs while educator and learner are at a distance from one another."[1] It typically involves the use of some type of educational media to transfer the course content between the instructor and the learner. The concept of distance education has evolved as a way of bridging the physical distance between instructional resources and expertise and learners who, for a variety of reasons, lack access to these resources.

A Historical Perspective

Distance education originated as an outgrowth of correspondence courses delivered by mail. It expanded to include electronic technology, beginning with the radio, and then television. Distance learning gained rapid visibility and recognition with the founding of the British Open University in 1969.[2] The British Open University broadcast its video course work throughout the United Kingdom on the BBC network. Rapidly, other government-supported "open universities" were established in other countries. Today, distance education has gained worldwide acceptance, extending educational opportunities across state and international boundaries. The dramatic pace of technologic innovation in telecommunication has supported a proliferation of education delivery solutions. Distance education is no longer limited to written text that arrives in the mail for students who memorize facts for tests. Also, distance learning is no longer limited to "talking heads" on a videotape or live television. Innovations in technology and educational strategies, combined with faculty development, have broadened the possibilities, potential, and performance of distance education.

Currently, distance education incorporates communication via satellite, terrestrial microwave, cable television, compressed video, desktop cameras, and the World Wide Web. These technologic advances make it possible to conduct courses at a distance using innovative, interactive, collaborative, practical, and meaningful approaches. For most of us, our typical experience with the television environment is that of a passive receiver. However, the interactive television and computer environments of distance education not only enable interactions between learners and content, but also learner-instructor and learner-learner interactions.[3]

A recent study involving university women with families showed that distance education decreased the role conflict and stress associated with balancing work, school, and family.[4] I believe these results are generalizable to a much broader population. Please permit me to share my personal experience with distance learning.

A Personal Perspective

Other than seeing broadcast instruction on television, my first experience with distance education was in 1989 when I was working on my doctorate. Dr Steven Olejnik

at the University of Georgia agreed to simultaneously teach his statistics course to local students in Athens and another class in Augusta. At that time, the technology was rather primitive, relegated to a telephone connection for the computer modem and audio connections for the teacher and students in each class. We could not rely on body language because we could not see the professor and he could not see us. Because less than 10% of communication is by the actual words, with the majority of communication being nonverbal,[5,6] it is no surprise that there was skepticism. However, that did not stop the course from proceeding. Lack of nonverbal communication did not deter me or the rest of our class from asking questions and interacting. The course was a success and the Augusta group performed equally well in the course, preliminary, and comprehensive examinations.

Dr Olejnik did a superb job of including our distant group in the interactions during class. We were also able to call him by telephone if we needed further clarification. (Today, E-mail, bulletin boards, and chat rooms offer even more opportunities to clarify student questions and provide feedback!) Dr Olejnik was well-prepared, friendly, and open to frequent interruptions to clarify, repeat, answer questions, or give examples. He kept the class lively and entertaining, inserting his dry, sometimes corny humor into the discussions. His knowledge, experience, enthusiasm for the subject matter, and genuine love of teaching were evident in the tone of his voice. You could "see" his enjoyment without seeing him. We continued with the course sequence in the same way the following semester. I learn and teach best by asking questions, so I preferred the live interaction even though it was limited to audio rather than a pre-taped videotape (which was the norm at the time).

Later in my graduate program, I made the 200-mile round-trip commute to University of Georgia to take my third and fourth statistics courses. After working most of the day and then driving for a couple of hours, I was able to sit in class and SEE Dr Olejnik! I can tell you that the commute put a strain on my time and energy, to the point that it made it more difficult for me to be interactive. The nonverbal communication I was privy to on the Athens campus was seriously offset by the fact that I was tired and by the knowledge that I had a long trip back home and would get home well after dark. It was tough making the commute twice a week each semester and keeping up with work and family. The live interaction was less important to me than the time commitment. When I was sitting in the Athens classroom I could actually see the teacher's smile, but I was less able to enjoy it! I did equally well in the Athens courses, but preferred not making the commute. I was satisfied with the learning, level of support, and interaction that occurred during the distance learning courses. I do not believe I learned more in the "live" courses as compared to the distance courses.

A Professional Perspective

What do others think about distance learning and its role in respiratory care? This issue of RESPIRATORY CARE includes an original study[7] that provides data about practicing respiratory therapists' (RTs) desire for baccalaureate degrees and attitudes toward distance education. Becker's study suggests that the majority of RTs who want a baccalaureate degree have positive attitudes toward distance education. Also, those RTs who are planning to pursue a baccalaureate degree are intending to enroll in programs that incorporate distance education. However, several practitioners in the study questioned how their employers would value this degree and if they could learn the course content at a distance. The RTs who intended to enroll in distance education felt that they would be more likely to have a flexible schedule and to get prompt feedback.

Today there is growing support for and opportunities to utilize distance education for certified respiratory therapists and registered respiratory therapists to earn baccalaureate and advanced degrees beyond their initial professional preparation. Students expect broader access to information and formal degrees based on trends in education, health care, and technology. In spite of any disadvantages, there are growing expectations for distance learning by consumers who have become accustomed to learning at home "surfing the net." It is reasonable to expect that we will see more distance education in respiratory care to meet advanced training needs, to offer baccalaureate and graduate degrees, and to fulfill state licensure requirements for professional continuing education.

The first American Association for Respiratory Care (AARC) education consensus conference concluded that self-directed home study programs should be eliminated for entry-level preparation and that the minimum entry-level should be at the associate degree level.[8] A year later, the second AARC education consensus conference recommended that distance education can be utilized to help underserved areas as a bridge to meet a higher educational level.[9] At first impression, these recommendations appear as a paradox. Further analysis suggests to me that there is no contradiction here. Rather, the recommendations are a reflection of the growth and development of respiratory care and also distance education. These AARC consensus conference reports[8,9] describe very different types of programs, with much variability in the philosophy, intent, student abilities, instructional methods, graduate outcomes, and program expectations. On the one hand, "home study" using written materials for entry-level preparation is discouraged. On the other hand, innovative distance educa-

tion programs can serve the gap for advanced and continuing education.

I believe that the respiratory care community recognizes the limitations of "home study" for entry-level preparation of individuals seeking professional credentials in respiratory care. We have also become savvy enough to recognize that using old methods for teaching and testing, with a heavy reliance on text, are limited in breadth and depth. I believe these statement are true whether respiratory care courses are offered via distance education or in the classroom. We expect more from education today. We also realize that training of new health care professionals must go beyond fact memorization, written tests, and clinical check-offs.[10,11] Students need to be better prepared to critically read, write, speak, and think beyond knowing respiratory care content or acquiring psychomotor skills.[12] Distance education can be incorporated to develop these skills when we go beyond using static text or "talking heads."

Since my personal experience as a graduate student, I have had opportunities as an educator and clinician to use distance learning. The key to successful distance education, when the students are capable, is the quality and quantity of class interaction that is built into each course. I base this opinion on the literature and on my own experiences as both student and teacher. Factors that can predict student success with distance education include the student's intentions and goals toward completion, higher entrance exam scores and grade point averages, completion of prior distance courses, a supportive family, and good college-level preparation.[13–17] One of the best predictors of success in distance education is the education background (prior formal training) of the student.[18]

In a distance education environment, the instructor is primarily responsible for creating effective interaction in the classroom.[19] His or her actions and behaviors work toward bridging the physical and psychological distance between on-site and remote-site classrooms. It is now possible for teachers to role model professional behaviors to students at a distance because class can be interactive; distance education is no longer dependent on sterile text. In spite of these advances, the million dollar question seems to be whether the educational experience is comparable and satisfactory. More research is needed to further answer this question in respiratory care.

Instructional Strategies, Opportunities, and Challenges

The distance teaching environment differs from that of the traditional classroom. This provides instructors both new opportunities and challenges. When conducting a program via distance education, several important practical considerations should be taken into account. The faculty must become comfortable in the distance teaching environment and familiar with available instructional support tools. Additional thought should be given to how course evaluation methods and student conflicts will be handled. The effectiveness of distance teaching is integrally related to how well an instructor uses the technology and understands its potential and limitations, and to his or her familiarity with associated instructional methods.[18]

In a conventional teaching environment, most instructors depend on the body language and facial expressions of the students as a simple classroom assessment tool. Using this method, it is relatively easy to determine if students are bored, puzzled, or engaged in the material. In an interactive television environment, it is often difficult to see or to assess the body language of individual students. Increasingly, faculty are incorporating the World Wide Web into their distance learning strategies. In Web-based classes using interactive computers, the students may not be visible at all. Therefore, instructors must consciously plan for interaction and feedback.[20,21]

Distance instructors often need to adopt different instructional philosophies, roles, teaching skills, and strategies. For example, the distance education teacher has to give more thought, planning, and implementation to the best way students can resolve their problems and questions. Interactions can be established in many ways, including student telephone calls, E-mail, bulletin boards, announcements on the course Web-site, chat rooms, and, of course, the postal system! The teacher has to communicate with students about the expected ways and best ways to interact with him or her, including regular office hours and/or class hours for planned interaction. Interaction must be planned and delivered for every aspect of each course, from the materials, to the delivery, through the evaluation methods and the grading. Then, distance education teachers must provide timely feedback, using the interactive methods they say they will use!

Handouts and other instructional support materials should be sent to the remote sites or posted on the Web, in advance of the program. Handouts are usually welcomed by program participants, provide space for note taking, and serve as a discussion tool. Faculty who offer distance learning courses must be given ample time to prepare materials in advance, interact with students in a timely way, and implement comprehensive evaluation methods.

Faculty development and preparation are essential to offer quality programs (on or off campus!) using traditional or distance education methods. Faculty are sometimes the most underevaluated and underrated resource in distance education. A considerable amount of faculty time can be spent on the actual development, delivery, and evaluation of courses conducted by distance education. This time is over and above the faculty time for their own professional growth and development needed to learn and use multimedia technologies. Problems for faculty and stu-

dents can occur whenever there is insufficient thought, planning, time, and resources devoted to all aspects of effective instruction.

Conclusions

Many universities and campuses throughout the world are attempting to meet learners' needs by incorporating distance education. Today, the AARC sponsors two baccalaureate-completion programs that offer courses via distance education—from Western Michigan University and the Center for Distance Learning at Empire State College.[22] California College for Health Sciences and Ottawa University also offer baccalaureate degree programs for RTs.[7] In addition, other respiratory therapy programs are also offering courses and complete programs for academic credit or continuing education. At the Medical College of Georgia we have developed a proposal to offer a baccalaureate degree via distance education to certified and registered RTs who want to continue their education and remain working in their local communities. Our needs assessment conducted by the local Area Health Education Center (AHEC) shows strong support from local hospitals and employers, who desire opportunities for their staff who seek additional education and the baccalaureate degree. Pending final approval, we anticipate offering our first external degree distance education program in Albany, Georgia, as early as the year 2000.

Many medical institutions have now reached a point where they are integrating telemedicine and distance education systems into their everyday operations for delivery of medical care and professional education in pulmonary medicine, allergy/immunology, and respiratory care.[23,24] However, practical experience and research are needed to define and develop distance education in respiratory care. What is the role of distance education in respiratory care now and into the future? What can distance education do for our profession? What are the possibilities and pitfalls? What are the needs of faculty and students? Are respiratory faculty resources stretched too thin when we add distance education courses or complete programs of study to our curricula? How should resources be obtained and allocated for distance education? How can programs work collaboratively to offer the types of programs needed by RTs? The latter questions pose the most challenge to me. Further research is needed to address these and other questions.

Whether we want it or not, distance education has become an integral component of all forms of education. We are moving toward internalization of distance learning whereby traditional institutions are using multimedia technology for all students. Course designers, developers, and faculty are asking "given the technologies of today and tomorrow, how can we best design education systems to meet learners' needs, whenever and wherever?"[25] Distance education will have an increasing role in the respiratory care profession in spite of any controversies.

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Attitudes Among Practicing Respiratory Therapists in a Midwestern State Toward Completing a Baccalaureate Degree and Toward Distance Education

Ellen A Becker PhD RRT and Chère C Gibson PhD

BACKGROUND: The respiratory care community has discussed the value of practicing respiratory therapists (RTs) completing baccalaureate degrees, but no study has identified how many RTs want a baccalaureate degree, their desired degree majors, or how RTs want academic courses delivered. METHODS: A random sample of 500 licensed RTs in a Midwestern state were mailed a questionnaire requesting information about their baccalaureate degree status, desire to complete a baccalaureate degree, course delivery options, attitudes and beliefs toward distance education, and demographic data. RESULTS: A 74% response rate was obtained. Sixty-four percent of the sample wants, is matriculating toward, or already has a baccalaureate degree. Of the survey respondents lacking a baccalaureate degree, 55% wanted the degree, and 83% of those wanted to matriculate within 5 years. The desired degree majors were management (33%), science (29%), advanced practice (29%), business (26%), and teaching (22%). Respondents wanted degree programs to grant experiential credit and offer part-time, evening, and weekend courses within 40 miles of their homes. Sixty-eight percent of degree seekers had positive intentions toward using distance education. The variables attitude and subjective social norm explained 46% of the variance. Several respondents questioned how their employers would value a degree earned via distance education and whether they could master the course content via distance learning. The RTs who intended to use distance learning felt they would have more flexible schedules, be more likely to get more prompt feedback, and develop a closer relationship with their instructors. CONCLUSIONS: Many RTs want a baccalaureate degree, but most of these need nontraditional education programs to accommodate their work and family obligations. Distance education can offer the desired flexibility, but few RTs have experience with distance education, and many need more information about distance education, including how their employers would value such a degree. [Respir Care 1999; 44(11):1337–1352] *Key words: baccalaureate degree, bachelors degree, distance education.*

Background

The respiratory care education community has frequently discussed the need for respiratory therapists (RTs) to extend their formal education. The American Association for Respiratory Care (AARC) held 2 education consensus conferences that concluded that entry level training should be at the associate degree level and that associate degree programs should allow matriculation to the baccalaureate degree level.[1,2] Specialty education should be integrated into the curriculum at the baccalaureate degree level. Reasons cited for increasing the duration of training include increased technology and increased scope of practice. Also, it was felt that RTs need advanced degrees to compete

See The Related Editorial on Page 1332

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with their colleagues from other professions for leadership positions in this era of downsizing.[1,2]

Despite this leadership from the respiratory care education community, little is known about how the majority of practicing RTs feel about increasing their education level. RTs in the work force may want to complete a baccalaureate degree to increase their knowledge base, gain a specialization, or prepare for graduate studies. The present study was undertaken to determine how RTs in a certain Midwestern state feel about completing a baccalaureate degree.

Continuing education poses several challenges for working RTs who might want to earn an advanced degree. Adult students need content delivered in a manner that fits into their busy work schedules and personal lives. A study involving university women with families showed that distance education was one university support structure that decreased the role-conflict and stress associated with balancing work, school, and family demands.[3] Distance education courses may offer a more responsive approach to RTs' personal and work schedules than traditional continuing professional education, and most distance education courses offer greater flexibility in the timing and location of learning than conventional education settings.[4,5]

Distance education is a means of delivering education in which the students do not need to be on campus to attend classes. Students may receive course content through the mail (written material, videotapes, or audio tapes), presented over an audio-teleconferencing, satellite, or television network, or sent through computer networks. Often, a variety of media are used for both the delivery of course content and interaction components. Students can communicate with their teachers and fellow classmates through private telephone conversations, teleconferences, computer messages, and the postal system. Many institutions, from small private colleges to major universities, offer degrees through distance education.[4,5]

RTs are not likely to take courses through distance education unless they believe that this method of course delivery will be effective. Many people have negative associations with and negative assumptions about distance education. Pittman addresses how films, novels, and other media often portray degrees earned through correspondence study as illegitimate.[6] Not all educators support distance education. One study noted that educators who had less experience teaching through distance education and those associated with higher-degree-granting institutions had less favorable opinions toward distance education.[7]

There are mixed views toward distance education within the respiratory care profession. A report from the AARC's first education consensus conference concluded that self-directed home study programs should be eliminated for entry-level professional preparation.[1] However, the second AARC education consensus conference recommended that distance education be used as a means to help underserved areas and, ironically, serve as a bridge to replace the home study programs they wanted to eliminate.[2] Support for distance education is stronger for practicing professionals who wish to complete a baccalaureate degree. The AARC sponsors baccalaureate completion programs from Western Michigan University and The Center for Distance Learning at Empire State College, both of which offer courses through distance education.[8] California College for Health Sciences and Ottawa University also offer distance education baccalaureate programs for RTs.

The second part of the present study measured RTs' views toward baccalaureate degree completion through distance education. We found only one prior study, in any profession, that examined pre-enrollment beliefs about distance education. In that study, prospective students were surveyed about using distance education to study oenology (wines and winemaking). Those researchers found that previous multimedia experience correlated with a positive view toward distance education; however, the study did not use a random sample and the instrument had no reliability testing.[9]

The present study posed the following questions:

1. How many practicing RTs want to complete a baccalaureate degree?
2. What variables affect enrollment in a baccalaureate degree program?
3. What variables affect practicing RTs' decisions to use distance education courses to complete their baccalaureate degrees?
4. What beliefs do RTs hold toward distance education as a means of completing a baccalaureate degree?

Methods

The population (N = 1,717) consisted of licensed RTs in a Midwestern state. After receiving human subjects approval, a questionnaire was mailed to 500 RTs. The questionnaire was designed to identify the desire for a baccalaureate degree and posed specific questions about completing the degree through traditional education programs and distance education. The questionnaire also requested demographic information.

Theoretical Framework for Distance Education Questions

Fishbein and Ajzen's Theory of Reasoned Action (TRA) was selected for the theoretical framework to study RTs' beliefs and attitudes toward distance education.[10] The TRA has been used successfully in the continuing professional education literature for predicting both intentions to participate[11] and behavior.[12] It proposes that behavior (in this case participation in a degree program) can be predicted

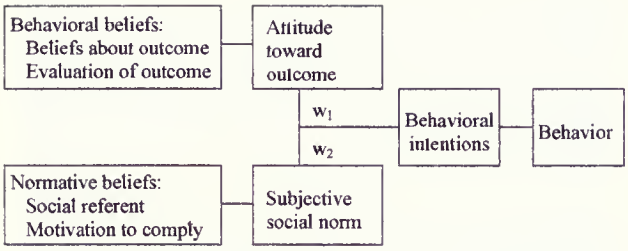

Fig. 1. Theory of Reasoned Action (TRA). (Figure adapted from Reference 14, with permission.)

from behavioral intentions, attitudes, and subjective social norm influences. These 3 variables mediate all external influences such as demographic variables, attitudes toward the target behavior, and personality traits. Figure 1 shows a schematic representation of this model.

The immediate precursor to predicting behavior is behavioral intentions. Behavioral intentions indicate the individual's general intention whether or not to participate. Attitudes toward the behavior and subjective social norm in turn affect the formation of behavioral intentions. The subjective social norm measures the impact of important referents on the study participant's intentions. The relative contributions of attitude and subjective social norm components differ. Equation 1, below, illustrates this relationship; in the equation, B, BI, A, and SSN are (respectively) behavior, behavioral intentions, attitudes, and subjective social norms. The values w_1 and w_2 indicate the relative weights of attitude and normative influences.

$$(1)\ B \approx BI = (w_1 \times A) + (w_2 \times SSN)$$

Another key feature of the TRA is its explanatory role. The TRA attempts to account for the underlying beliefs that control the attitude and subjective social norm scores. The theory claims that each behavior has an associated set of salient beliefs. These beliefs represent the range of outcomes likely to occur as a result of engaging in the behavior. Comparing the direct measures of attitude and subjective social norm with estimated belief measures tests the TRA's explanatory role.

The estimated measure for the attitude variable is referred to as the behavioral belief score because it measures how respondents feel about specific beliefs related to the behavior. Respondents indicate the outcome they expect from each belief and give a positive or negative evaluation of each belief. For example, respondents in this study answered questions about whether the use of media will make distance education more engaging and whether distance education will be more convenient for working therapists, and rated whether these outcomes are positive or negative. Equation 2 is an algebraic representation of the behavioral belief score.

$$(2)\ BB = \Sigma b_i e_i$$

In Equation 2, BB is the behavioral belief score, b_i is the expected outcome that will occur from participating in a behavior, and e_i is the respondent's evaluation of that outcome. The belief score is calculated by summing the products of the expected outcome and evaluation scores from all beliefs.

The normative belief score serves as an estimation of the subjective social norm variable. Each individual has social referents (friends, colleagues, or employers) that may influence decision-making. The normative belief score measures how the individual thinks important referents would want the individual to behave. The individual's motivation to comply with each referent is also measured. Equation 3 summarizes the normative belief measure.

$$(3)\ NB = \Sigma n_i mc_i$$

In Equation 3, NB is the normative belief score, n_i represents how a study participant feels important referents would want him/her to behave, and mc_i is the participant's motivation to comply with each referent. The summed products of referent beliefs and motivation-to-comply scores form the normative belief measure.

Both the predictive and explanatory roles of the TRA help to understand participation. The direct measures of behavioral intentions, attitude, and subjective social norm predict who will participate. The indirect measures (beliefs) of attitude and subjective social norm explain the basis for the participation decision.

The literature supports adding 2 additional variables to the TRA for predicting participation intentions. The subjective personal norm considers the respondent's moral obligation to participate. Because this variable was found to be significant in studies of oral surgeons and veterinarians, it was also included in the present study.[11,12] Perceived behavioral control is the second additional predictor variable. Ajzen and Madden suggest that the perceived behavioral control variable improves the prediction of intentions when potential participants have less volitional

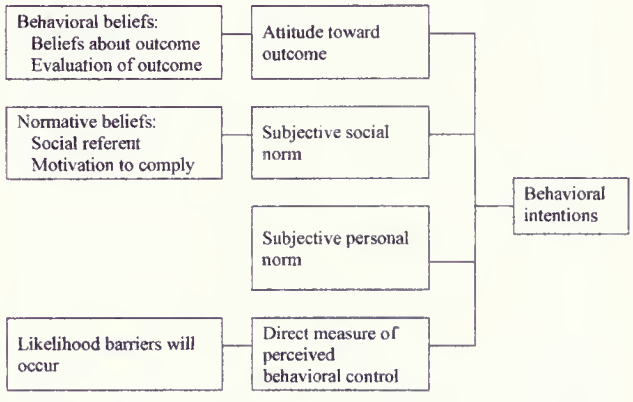

Fig. 2. Modified Theory of Reasoned Action (TRA). (Figure adapted from Reference 14, with permission.)

control over their situation.[13] The majority of RTs work in patient care and not management positions. As a result, they have limited control over their own work hours, work days, work shifts, and start times. Perceived behavioral control may improve the prediction of intentions because of the limited control RTs have over their work schedules. Figure 2 shows how the 2 additional predictor variables fit within the TRA.

Instrument Development

The survey instrument requested information about current degree status. Respondents who did not have a baccalaureate degree and were not matriculating toward one were asked to rate their desire to pursue a baccalaureate degree and to state their preferences about degree major, course times, travel distance, matriculation time frame, and method of course delivery. Respondents who had a baccalaureate degree or who were matriculating toward one were asked when they had earned or would earn that degree (before or after their respiratory care training), the type of degree they earned, and if they used distance education to complete any of their courses.

The development of each variable relevant to the distance education questions followed the guidelines recommended by Ajzen and Fishbein.[14] Further information on each scale's development can be found elsewhere.[15] All measures in this section utilized a 7-point Likert scale.

Intention. Respondents were asked to rate their intentions to complete a baccalaureate degree through distance education, using a bipolar scale with the words "agree" and "disagree" as the end points of the scale.

Attitude. The literature supports use of a semantic differential scale for the attitude measure.[11,12,16,17] A list of 48 adjective pairs from the distance education and continuing professional education literature was submitted to 7 experts in distance education (3 from the field of respiratory care, 2 from nursing, and 2 from adult education). Adjective pairs given a rating of 3 or 4 on a scale of 1 (not relevant) to 4 (extremely relevant) were included in the final attitude measure, provided there was at least 80% inter-rater reliability. The scale resulting from the comments of the expert panel comprised 11 adjective pairs.

Respondents used a bipolar scale to rate the evaluative adjective pairs: interesting/boring, affordable/costly, useful/useless, appropriate/inappropriate, time-saving/time-consuming, creative/unimaginative, successful/unsuccessful, practical/impractical, nonthreatening/threatening, active/passive, and simple/complex. Adding the scores from each adjective pair derived the attitude score.

Subjective Social Norm. The respondents were asked to rate what most people important to them felt the participants should do about using distance education courses to complete a baccalaureate degree. This response was scored on a bipolar scale in which "likely" and "unlikely" were the end points.

Behavioral Beliefs and Normative Beliefs. Belief statements were developed by a convenience sample (n = 14) of the study population for the behavioral belief (estimated attitude) score and normative belief (estimated subjective social norm) score. This group size is consistent with Ajzen and Fishbein's recommendations.[14] Members in the convenience sample varied in their baccalaureate degree status, years in the respiratory care profession, and their opinions about what was the best method to earn a baccalaureate degree. Group members were asked to identify positive and negative beliefs they or others might have about completing a baccalaureate degree through distance education (behavioral beliefs). Belief statements repeated by 75% of the respondents were retained for the BB measure. Ten behavioral belief statements for the attitude dimension resulted and were scored on a scale with "likely" and "unlikely" as end points. The evaluation for each behavioral belief outcome was rated with end points of "good/bad" or "important/unimportant." The behavioral belief score consisted of the summed products of belief outcome and its corresponding evaluation.

The same convenience sample was asked to list reference groups that would probably influence an RT's intentions to complete a baccalaureate degree through distance education. Again, the criterion of 75% agreement was used to determine inclusion. Five referents for this population (current employer, potential future employers, family members, friends, and coworkers) were identified. The ratings for the subjective social normative beliefs and motivation to comply with each referent were measured with a scale using "likely" and "unlikely" as end points. The beliefs were scored on a bipolar scale and the motivation-to-comply score used a unipolar scale. The respondents' normative belief scores were generated by summing the products of the belief score for each important referent with its corresponding motivation-to-comply score.

Subjective Personal Norm. The survey asked respondents to rate their moral obligation to complete a baccalaureate degree. The wording for the subjective personal norm measure needed to deal carefully with the context statement of distance education, because two issues might have been confused if respondents had been asked to rate their obligation to use distance education to complete a baccalaureate degree. One issue is the felt obligation of completing a baccalaureate degree. The second issue is the felt obligation to complete a baccalaureate degree through

distance education courses. In the latter example, many RTs may feel obligated to complete a degree through distance education because they have limited alternatives. Therefore, the context of distance education was omitted from this question.

A discrepancy in the literature prompted the use of 2 different measures for the subjective personal norm variable.[11,12] The first subjective personal norm measure used a single question that measured respondents' moral obligation to complete a baccalaureate degree. Two questions comprised the second measure, where respondents rated their moral obligation to complete a baccalaureate degree along with their willingness to act upon their belief. The product of the belief and willingness-to-act scores formed this second expectancy/value subjective personal norm measure. Both the belief and the willingness to comply items were rated on bipolar scales. The belief statement scales had "true" and "false" as end points, and the willingness-to-comply scale used "willing" and "unwilling" as end points.

Perceived Behavioral Control. The perceived behavioral control variable was measured through both a direct and belief measure. The direct measure utilized 3 similarly-worded questions that asked respondents to rate the degree to which they felt they had control over taking distance education courses to complete a baccalaureate degree. Participants rated these 3 questions on unipolar scales. The sum of the 3 values composed the direct measure of perceived behavioral control.

The convenience sample (n = 14) developed the content for the indirect measure of perceived behavioral control. These RTs listed variables that would likely prevent them from taking distance education courses to complete a baccalaureate degree. Items that had 75% agreement were included in the survey instrument. These items were the comfort of using a VCR or computer for learning, access to a VCR or computer for learning, education expenses, time constraints imposed by family and work schedules, and the need to drive more than 40 miles to classes. Respondents estimated the likelihood that each of the above variables would prevent participation on a unipolar scale with "extremely unlikely" and "extremely likely" as end points. The sum of scores from the 8 items on this scale composed the indirect measure of perceived behavioral control.

The final section of the questionnaire asked for demographic information. Respondents identified their race, gender, employment status, professional credentials, years of work experience, highest degree held, and type of work environment. Space was provided for respondent comments.

A pilot test of the questionnaire was conducted using a representative sample of the population (n = 26). Pilot study respondents recommended simplifying the instructions, alternating positive and negative belief statements to prevent bias, changing the order of scales to move from simple to complex and from general opinions to more personal statements, and rewording statements to improve clarity. Financial resources limited the pilot study's sample size. Thus, study of the survey instrument's reliability and validity tests were deferred to the actual study results. The findings are reported below for clarity.

Reliability and Validity. The reliability measures using Cronbach's α from the study data were attitude (0.85), behavioral beliefs (0.29), normative beliefs (0.84), and perceived behavioral beliefs (0.42). The reliability of scales for attitude and normative beliefs indicates internal consistency, but the scales were inconsistent for assessment of behavioral beliefs.

The 3 questions for the direct measure of perceived behavioral control were subjected to principal components analysis to test construct validity. The 3 questions only explained 32% of the variance, which indicates that the 3 questions did not measure a single construct as intended. Thus, findings utilizing the perceived behavioral control variable could not be validated.

The correlation between the predictor variables and their corresponding beliefs was another measure of construct validity. The construct validity between significant predictor variables and beliefs showed a moderate correlation (r = 0.513) between the attitude measure and behavioral beliefs, and a moderately high correlation (r = 0.699) between the subjective social norm and normative beliefs measure. Both correlations were significant ($p < 0.001$).

Content validity was established by the use of an expert panel to develop the attitude measure, representative members of the population to construct the belief statements, and feedback from pilot study participants.

Sample Size

The power required for multiple regression analysis, number of RTs desiring a baccalaureate degree, estimated response rate, and a planned within-study replication influenced the sample size determination. The effect size (R^2) for prior studies looking at participation intentions in continuing professional education averaged 0.40.[11,12] Using an effect size of 0.40 combined with a desired power of 0.80, 4 predictors, and an α level of 0.05 yielded a sample size of 24.[18] This calculated value is low compared to the rule of thumb that suggests 10 respondents for each predictor variable.[19] Therefore, the latter formula was used to compute this study's sample size, requiring 40 members for each group.

After calculations were made to achieve power, we examined additional variables to determine our total sample size, including estimates of RTs' desires for baccalaureate degrees and survey response rates. The AARC's 1992 Human Resources Survey indicated that 88% of RTs in the

Midwestern state's region did not have a baccalaureate degree.[20] The representative group of pilot-study participants estimated that 30% of RTs without baccalaureate degrees would want to pursue one. Response rates for survey research can be low, but the literature suggests that surveys performed with 2 rounds of follow-up mailings can yield a 75% response rate.[21] The required power, estimation of RTs' desire for baccalaureate degrees, and a predicted response rate of 60% required a sample size of 500.

Procedures

Questionnaires were mailed to a random sample of 500 licensed RTs in a Midwestern state, randomly selected from an alphabetical listing of licensed RTs. A sequence of selecting every third name twice, then the fourth name from a list provided by the state's board of regulation and licensing was repeated until enrollment reached 500. The return address envelopes were numerically coded to keep track of responders. Two rounds of follow-up mailings were sent to nonresponders. After completion of the data collection, 30 nonresponders were randomly selected to collect demographic data and information about their desire for a baccalaureate degree. The identification of nonresponders contacted was limited to 30 so that there would be sufficient data for statistical analyses while respecting the decision of those RTs who chose not to participate. We contacted as many of these 30 nonresponders as possible within the time available; 23 were reached.

Data Analysis

There were 2 general categories of data analysis. Analyses were conducted to test the representativeness of the sample and the research questions.

Representativeness of the Sample. The respondents' demographic data were compared with corresponding regional data from the AARC's 1992 Human Resources Survey to determine how well the survey responders represented the population under study.[20] The variables gender, race, number of respondents holding a baccalaureate degree, and possession of the RRT credential were compared through the chi-square goodness of fit at $\alpha = 0.05$. Similarly, survey responder data were compared to the AARC's data encompassing all regions (national data) to assess whether the study results could be generalized nationally.

To determine response bias, the survey's responders and nonresponders were compared through the chi-square test of homogeneity. The comparison variables were gender, baccalaureate degree status, presence of RRT credential, and desire to complete a baccalaureate degree. All chi-square tests were run using SPSS for MS Windows Version 7.0 statistics software package (SPSS, Chicago, Illinois).

Research Questions. Response frequencies and proportions were reported for all questions relating to the number of respondents who desire a baccalaureate degree, the types of degree majors respondents want, how soon respondents want to begin baccalaureate programs, and how respondents want course work delivered. A 95% confidence interval was calculated for each proportion.

Additional data analysis was performed on the responses from those who had previously earned or were matriculating toward a baccalaureate degree. The survey requested the degree major and university name. Degree programs were categorized as either "traditional" (on-campus) programs or, if the program granted experiential credit or held longer, less frequent classes, as "nontraditional."

The following procedures were undertaken prior to analysis of questions relating to distance education. Respondents needed to complete at least 80% of the TRA subscales' items to have their responses included in the final data analysis. The researchers prorated the qualifying scale scores that contained missing elements.

Respondents were randomly assigned to 2 groups prior to the analysis for the within-study replication. These responses were entered into the Systat Version 5.0 software program (Statistical Solutions Ltd, Saugus, Massachusetts). Odd-numbered and even-numbered entries were assigned to Groups 1 and 2, respectively. Independent analyses were carried out on each group.

Multiple regression was used to determine which variables affected the decision to use distance education; in these calculations, intentions was the dependent variable and attitude and subjective social norm were the independent variables. Attitude and subjective social norm were added to the regression equation first because these predictor values consistently had significant beta weights in prior studies.[10–13] The beta weights for each predictor were tested at a familywise $\alpha = 0.05$. Only predictors with significant beta weights were retained in the regression equation.

A second regression analysis was conducted by adding 2 additional predictor variables, subjective personal norm and perceived behavioral control. Values for both measures of subjective personal norm were tested. These variables were added stepwise with the α levels split equally to maintain a familywise $\alpha = 0.05$.

The stability of the resulting regression equation was tested through a within-study replication. The regression equation from Group 1 was used to estimate the intention score for all respondents. A correlation between each group's estimated and measured scores was computed. The correlations were statistically tested at $\alpha = 0.05$ using Fisher's z tests of difference.

The validity of measured beliefs about distance education was determined by correlating significant predictor variables with their corresponding beliefs. Belief sets that

Table 1. Comparison of Demographic Data to Regional Proportions* (n = 364)†

	Observed n (% total)	Regional Proportion (%)	Chi-square	p
Female	260 (71.8)	71.3	0.049	0.825
Male	102 (28.2)	28.7		
Baccalaureate degree	69 (19.0)	13.4	9.89‡	0.002
No baccalaureate degree	294 (81.0)	86.6		
RRT credential	187 (51.8)	42.4	13.03‡	< 0.001
No RRT credential	174 (48.2)	57.6		
White	342 (96.6)	88.8	21.66‡	< 0.001
Non-White	12 (3.4)	11.2		

*Regional proportions are from Reference 20.
†Items with missing responses were omitted from the analysis.
‡$p < 0.05$.
RRT = registered respiratory therapist.

Table 2. Comparison of Demographic Data to National Proportions* (n = 364)†

	Observed n (% total)	National Proportion (%)	Chi-square	p
Female	260 (71.8)	62.3	14.00‡	< 0.001
Male	102 (28.2)	37.7		
Baccalaureate degree	69 (19.0)	16.3	1.94	0.16
No baccalaureate degree	294 (81.0)	83.7		
RRT credential	187 (51.8)	38.7	26.12‡	< 0.001
No RRT credential	174 (48.2)	61.3		
White	342 (96.6)	82.1	50.76‡	< 0.001
Non-White	12 (3.4)	17.9		

*National proportions are from Reference 20.
†Items with missing responses were omitted from the analysis.
‡$p < 0.05$.
RRT = registered respiratory therapist.

had a significant correlation were compared through a one-tailed t test of means to determine which beliefs differentiated RTs intending to complete a baccalaureate degree through distance education from those who did not intend to use distance education. Participants who rated a "slight" to "extremely likely" intention to complete a baccalaureate degree through distance education were classified as intenders. The nonintenders had "neutral" to "extremely unlikely" intentions to use distance education. Each analysis was tested at an $\alpha = 0.05$. The one-tailed test was selected because it was highly likely that intenders would rate positive belief outcomes and belief evaluations more highly than nonintenders.

Results

Sample

A 74% (n = 364) response rate resulted from the 494 deliverable survey instruments. The demographic data were compared to the AARC's regional data to test the representativeness of the sample. Table 1 shows that there were no differences in gender between the 2 groups, but the comparison categories of baccalaureate degree status, RRT credential, and race had statistically significant differences. Table 2 shows that the sample differed from the AARC's national proportions in gender, RRT credential, and race, but that the percentage with baccalaureate degrees matched the national sample.

Table 3 shows that responders and nonresponders differed in gender and desire for a baccalaureate degree. More nonresponders were men who did not want a baccalaureate degree. Responders and nonresponders did not differ in frequency of holding baccalaureate degrees or RRT credentials.

Table 3. Responder and Non-Responder Demographic Data*

	Responders n (% total)	Non-Responders n (% total)	Chi-square	p
Female	260 (71.8)	10 (43.5)	8.29†	0.004
Male	102 (28.2)	13 (56.5)		
Baccalaureate degree	69 (19.0)	2 (8.7)	1.53‡	0.216
No baccalaureate degree	294 (81.0)	21 (91.3)		
RRT credential	187 (51.8)	13 (56.5)	0.193	0.660
No RRT credential	174 (48.2)	10 (43.5)		
Desire baccalaureate degree§	172 (57.1)	7 (31.8)	5.32†	0.021
Do not desire baccalaureate degree‖	129 (42.9)	15 (68.2)		

*Items with missing responses were omitted from the analysis.
†$p < 0.05$.
‡The expected value for one cell was < 5.
§Includes the number of respondents desiring a baccalaureate degree or who are currently enrolled in a degree program.
‖The number of respondents who do not have a baccalaureate degree and do not desire one.
RRT = registered respiratory therapist.

Respondents Who Desire a Baccalaureate Degree

Of the 364 survey respondents, 17% already had a baccalaureate degree and 47% were interested in pursuing a baccalaureate degree. Among those who wanted a baccalaureate degree, 6% were enrolled in a degree program. Table 4 summarizes these results.

The following results came from respondents (n = 150) who desired a baccalaureate degree but were not yet en-

Table 4. Desire for Baccalaureate Degree

	n	% of Total (*n* = 364)	95% CI
Want baccalaureate degree	150	41	0.36, 0.46*
Already enrolled in baccalaureate program	22	6	0.04, 0.09*
Currently hold a baccalaureate degree	63	17	0.14, 0.22*
Do not want a baccalaureate degree	129	36	0.31, 0.41*

*Significant (CI < 0.25 < CI).

Table 5. Times and Days RRTs Would Like Classes to be Held

	n	% of Total (*n* = 150)*	95% CI
0800–1500 Weekdays	60	40	0.32, 0.49†
1500–1700 Weekdays	48	32	0.25, 0.40†
1700–1900 Weekdays	85	57	0.49, 0.64†
1900–2100 Weekdays	79	53	0.45, 0.61†
1200–1600 Fridays	34	23	0.17, 0.30†
1600–2100 Fridays	41	27	0.21, 0.35†
0800–1200 Saturdays	66	44	0.36, 0.52†
1200–1600 Saturdays	34	23	0.17, 0.30†
0800–1200 Sundays	43	29	0.22, 0.36†
1200–1600 Sundays	30	20	0.14, 0.27†

*Only the 150 people desiring a baccalaureate degree answered this question. Study participants were instructed to check as many responses as they wished.
†Significant (CI < 0.10 < CI).
RRT = Registered respiratory therapist.

Table 6. Willingness to Travel for Baccalaureate Degree Education

	n	% of Total (*n* = 150)*	95% CI
< 20 miles	54	36	0.29, 0.41†
21–40 miles	68	45.33	0.38, 0.53†
41–60 miles	26	17.33	0.12, 0.24†
> 60 miles	2	1.33	0.004, 0.05†

*Only the 150 people desiring a baccalaureate degree answered this question.
†Significant (CI < 0.25 < CI).

rolled in a degree program. The most popular desired degree major was management (33%), followed closely by science (29%), advanced practice (29%), business (26%), and teaching (22%). Eleven percent indicated other degree majors. Respondents could select as many responses as they wished, and they listed majors both inside and outside the health professions, including nursing, echocardiography, social service, physical trainer, dental hygiene, medicine, computers, drafting, art, library science, and undecided.

Respondents also rated their anticipated course load and matriculation time frame. Only 4% wanted to enroll full-time. Thirty-seven percent wanted to enroll within the next 2 years, 46% wanted to enroll within 2–5 years, and 17% wanted to enroll ≥ 5 years in the future. Regarding traditional face-to-face course delivery systems, the survey asked about desired class times, willingness to travel, and willingness to relocate in order to enroll in a degree program. Respondents could select multiple responses for the meeting-times question. Table 5 summarizes the responses regarding meeting times, among which the most popular was weekday evenings (53–57%), followed by Saturday mornings (44%) and morning and afternoon weekday hours (40%). Regarding travelling for courses and willingness to relocate (Table 6), at least 81% did not want to travel more than 40 miles one-way for courses. Only 5% of respondents were willing to relocate. Sixty-eight percent expressed "slight" to "extremely likely" intentions to use distance education to pursue their degree at a distance (Table 7).

Graduated and Matriculating Respondents

At the time of this study, 63 respondents (17%) had a baccalaureate degree. Of these, 59% earned their degrees prior to entering the respiratory care profession. The remaining 41% completed the degree after working in the profession. Table 8 shows the categories of degree majors earned at various career stages. Respondents who earned degrees prior to their respiratory care training had more degree majors in the health and physical sciences than those who earned their degrees later. Business management and administration were the most popular degree majors for respondents who earned their baccalaureate degree after entering the respiratory care field.

The vast majority (94%) of those who earned their degrees prior to entering the respiratory care profession had pursued traditional on-campus degree courses, whereas only 36% of those who completed their baccalaureate degrees after entering the profession, and 47% of current enrollees, attended traditional on-campus degree programs. These 3 groups, as a whole, had little experience with

Table 7. Intentions to Use Distance Education to Complete a Baccalaureate Degree

	n	% of Total (*n* = 150)*	95% CI
Extremely disagree	0	0	0.00, 0.03†
Quite disagree	5	3	0.01, 0.08†
Slightly disagree	4	3	0.01, 0.07†
Neither	38	25	0.19, 0.33†
Slightly agree	57	38	0.31, 0.46†
Quite agree	34	23	0.17, 0.30†
Extremely agree	10	7	0.04, 0.12†
Did not answer question	2	1	

*Only the 150 people desiring a baccalaureate degree answered this question.
†Significant (CI < 0.14 < CI).

distance education. Only 14% had taken some of their course work through distance education.

Variables Affecting Intentions to Use Distance Education

There were 142 useable survey instruments that involved calculations using the TRA. Intentions were regressed simultaneously on attitude and subjective social norm for Group 1 data. The regression equation produced a significant multiple $R = 0.691$, $F(2, 68) = 31.02$, $MSE = 0.72$, $p < 0.001$. The multiple $R^2 = 0.48$, however, reduces to 0.46 when the variance is adjusted for the number of predictors. These results had a power of 0.99+ and the beta weights for attitude and subjective social norm were both significant.[18] Equation 4 is the formula for predicting intentions based on Group 1 data.

(4) intentions = −0.482 + 0.855(attitude) + 0.314(subjective social norm)

Next, each measure of subjective personal norm and the single measure of perceived behavioral control were added to the 2-predictor model and tested at an $\alpha = 0.0167$. Neither measure of subjective personal norm nor perceived behavioral control reached significance in either group.

Estimated intention scores for all respondents were calculated based on the regression equation derived from Group 1 data. Correlations between the estimated and measured intention scores showed that $r = 0.691$ for Group 1, and $r = 0.375$ for Group 2.

A scatter plot showing the relationship between the predicted values for Group 2 data and measured intention scores revealed one obvious outlying score. This score belonged to a respondent who recorded extreme values for most responses. The outlying score was removed from this and all subsequent analyses of Group 2 data. The revised correlation on $n = 70$ cases for Group 2 improved to $r = 0.653$. This large change in correlation coefficient indicates how far the outlying score strayed from the majority of scores, which supports our decision to remove it.

Fisher's z tests of difference showed that the correlation coefficients for both Group 1 and the revised Group 2 data did not differ ($p = 0.655$). As a result, the regression equation for Group 1 data accurately predicted values for Group 2, demonstrating stability in the regression coefficients. Tables 9 and 10 summarize all of the regression data.

Beliefs About Distance Education

The specific behavioral and normative beliefs were evaluated by the t test of means to see which beliefs differentiated intenders to use distance education from nonintenders. Tables 11 and 12 summarize these findings.

Discussion

The present study had an excellent response rate, 74%, consistent with the literature's expectation of 75% for 2 rounds of follow-up mailings.[21] However, these results do not represent the entire population. A greater percentage of RTs who did not have baccalaureate degrees, lacked the RRT credential, and who were white responded to the survey. The real differences, however, were small. It is unclear whether this discrepancy was due to the comparison group or response bias. The AARC regional comparison data utilized a multi-state grouping, whereas in the present study all data came from a single state.

Compared to the AARC's national proportions, the responders in the present study were significantly more likely to be female, RRT credentialed, and white. The only similarity between the 2 groups was the percentage of RTs holding baccalaureate degrees. Thus, this study's findings cannot be generalized to reflect opinions of RTs across the country.

The responder and nonresponder data also showed some differences. There were relatively more female responders and more responders who wanted baccalaureate degrees. Respondents without baccalaureate degrees may have felt a stronger stake in the study's outcome. Because of this response bias, our measurement of the number of respondents who desire a baccalaureate degree is assumed to be high. However, the higher response rate from this baccalaureate-seeking group does not adversely affect the integ-

Table 8. Category of Degree Major and Timing of Respiratory Care Training*

	Earned Before RC Training		Earned After RC Training		Degree in Progress	
	n (% total)	95% CI	*n* (% total)	95% CI	*n* (% total)	95% CI
Social sciences	7 (18.9)	0.01, 0.34	0	0.00, 0.13†	0	0.00, 0.15†
Health sciences	8 (21.6)	0.11, 0.37	3 (11.5)	0.04, 0.29	5 (22.7)	0.10, 0.43
Liberal arts	6 (16.2)	0.08, 0.31	2 (7.7)	0.02, 0.24	2 (9.1)	0.03, 0.28
Physical sciences	9 (24.4)	0.13, 0.40	0	0.00, 0.13†	2 (9.1)	0.03, 0.28
Education	4 (10.8)	0.04, 0.25	2 (7.7)	0.02, 0.24	1 (4.5)	0.01, 0.22
Business management/ administration	3 (8.1)	0.03, 0.21	15 (57.7)	0.39, 0.75†	8 (36.4)	0.20, 0.57†
Did not answer question	0		4 (15.4)		4 (18.2)	

*Only the respondents who had a baccalaureate degree or were currently enrolled in a baccalaureate degree program answered this question.
†Significant (CI < 0.17 < CI)
RC = respiratory care.

Table 9. Regression of Intention on Attitude and Subjective Social Norm for Group 1 and Group 2

	B	SE B	β	p
Group 1†				
Attitude	0.855	0.139	0.562‡	< 0.001
SSN	0.314	0.105	0.274‡	0.004
Group 2§				
Attitude	0.749	0.137	0.531‡	< 0.001
SSN	0.212	0.081	0.253‡	0.011

†$R^2 = 0.46$, $n = 71$, $p < 0.001$
‡$p < 0.05$.
§$R^2 = 0.41$, $n = 70$, $p < 0.001$
B = beta weight. SE B = standard error of the beta weight. β = standardized beta weight.
SSN = subjective social norm.

rity of the other study questions that specifically targeted the opinions of these degree seekers.

Our results indicate that 57% of respondents without a baccalaureate degree want to pursue one, but we assume that 57% value is falsely elevated because the nonresponder data indicated a response bias. When the nonresponder data are added into the total responder pool, 55% of sampled RTs appear to desire baccalaureate degrees. If all of the nonresponders had a negative view toward completing a baccalaureate degree, the number who want a baccalaureate degree would be 42%.

Sixty-four percent of respondents want, are matriculating toward, or have baccalaureate degrees. Respondents' intentions to pursue baccalaureate degrees support the AARC education consensus conference findings that further formal training is needed.[1,2] RTs want courses located within 40 miles of their homes, and most would prefer evening and weekend courses, though some respondents wanted morning and afternoon weekday courses. Work schedule conflicts will likely result for some RTs no matter when programs offer courses, given that the respiratory care profession provides 24-hour patient care.

Degree majors in management (33%), advanced practice (29%), science (29%), and business (26%) appealed most to the respondents who desire a degree. However, respondents were allowed to select more than one response for degree majors, so the percentages reported herein for each major are high, because it is unlikely that many RTs will earn all of the majors they selected. The selection of multiple majors does, however, support the respondents' written comments about not knowing which degree major will be most helpful in their professional careers.

The desire of RTs to select an advanced practice degree (29%) is important for the profession of respiratory care. A baccalaureate degree in respiratory care places RTs on par with other allied health professionals who have baccalaureate degrees in their respective professions. Furthermore, increased education provides the potential for involvement in advanced procedures, thereby advancing the profession of respiratory care.

The degree majors in which degree-desiring respondents expressed interest differed somewhat from the majors held by the degreed respondents. Respondents who earned their degree prior to entering the profession had a broader range of majors, as would be expected. Those earning degrees while practicing in the profession earned degrees primarily in business management or administration.

Respondents who were matriculating toward baccalaureate degrees were more often pursuing health science majors. These health science majors may leave the respiratory care profession upon completion of their degree, although none of these respondents clearly indicated their intentions in their survey responses. However, a few re-

Table 10. Tests of Beta Weights for SPN(1)*, SPN(2)†, and PBC‡ as Additional Predictors in the Theory of Reasoned Action

	Group 1 (n = 71)			Group 2 (n = 70)		
	B SE B	β	p	B SE B	β	p
Test of SPN(1)						
Attitude	0.859	0.565§	< 0.001	0.765	0.543§	< 0.001
	0.140			0.146		
SSN	0.307	0.268§	0.005	0.214	0.256§	0.011
	0.106			0.082		
SPN(1)	0.032	0.054	0.544	−0.020	−0.032	0.749
	0.053			0.063		
Test of SPN(2)						
Attitude	0.841	0.553§	< 0.001	0.773	0.806§	< 0.001
	0.142			0.146		
SSN	0.311	0.272§	0.004	0.221	0.264§	0.010
	0.105					
SPN(2)	−0.009	−0.048	0.597	−0.018	−0.052	0.619
	0.016			0.034		
Test of PBC						
Attitude	0.770	0.508§	< 0.001	0.667	0.473§	< 0.001
	0.143			0.145		
SSN	0.317	0.277§	0.003	0.199	0.237§	0.016
	0.103			0.081		
PBC	0.085	0.177	0.054	0.077	0.159	0.117
	0.043			0.048		

*SPN = subjective personal norm. SPN(1) = SPN measured by a single question. R^2 = 0.46, 0.41 ($p < 0.05$) for Groups 1 and 2, respectively.
†SPN(2) = SPN measured by the product of two questions. R^2 = 0.46, 0.41 ($p < 0.05$) for Groups 1 and 2, respectively.
‡PBC = perceived behavioral control. R^2 = 0.48, 0.43 ($p < 0.05$) for Groups 1 and 2, respectively.
§$p < 0.0167$.
SSN = subjective social norm.
B = beta weight, SE B = standard error of the beta weight, β = standardized beta weight.

spondents who wanted to obtain a baccalaureate degree commented:

> . . . I would be *very* hesitant to get a degree in respiratory care, especially in this age of health care, with departments closing, I am unsure of the future of this profession. I would be more likely to get a degree in another area.
>
> . . . with the re-engineering that is going on in so many hospitals, I see therapists going back to nursing school due to unsurety of our positions.
>
> . . . I would not invest 10 cents in any RT baccalaureate education. I *would* spend money to re-train for a different job. What a shame!

Sixty-nine percent of respondents who earned their degrees after being in the profession used nontraditional education programs. These nontraditional programs granted credit for experiential learning and held classes once a week, either on weekday evenings or weekends. The 2 most popular nontraditional programs offered degree majors in business management and business administration. The convenience of nontraditional programs might be the reason for the narrow range of degree majors among respondents earning degrees after respiratory care training compared with respondents' desire to choose a broader range of majors.

The issue of convenience is addressed in the adult education literature. Several participation models include minimizing barriers as a variable.[22–24] Literature specific to adult degree completion programs emphasizes the need that programs address adults' particular education needs. One study found that adults' perceptions that administration and faculty recognized and arranged for the needs of adult students was the primary reason for their success.[25] Another study[26] identified criteria for effective adult degree completion programs, among which: the need for established assessment criteria and methods of acquiring credit for prior learning; provision of courses and instruction at times and places compatible with adult learner lifestyles; and provision of financial aid and financial planning for adult learners. The nontraditional programs attended by respondents provided for the adult learners by

Table 11. Comparison of Mean Behavioral Beliefs Between Intenders* and Non-Intenders†‡

	Belief outcome (b_i)			Evaluation of belief (e_i)			Product (b_ie_i)		
	M_I M_{NI}	MSE n	t p	M_I M_{NI}	MSE n	t p	M_I M_{NI}	MSE n	t p
More convenience for working therapists	2.031 1.773	0.209 141		3.320 2.523	0.661 141		7.010 4.682	1.423 141	
No personal interactions with classmates	0.103 1.000	0.293 141	−3.062§ 0.003	−0.052 0.273	0.263 141		1.000 0.773	0.525 141	
Not needing to attend classes on campus	0.804 0.114	0.321 141	2.156§ 0.033	1.691 0.955	0.245 141	3.004§ 0.003	2.175 1.341	0.665 141	
Prompt instructor feedback through media	1.485 0.977	0.255 141	1.991§ 0.048	2.186 2.159	0.169 141		3.876 2.341	0.653 141	2.351§ 0.020
More flexible class schedules	2.433 1.907	0.161 140	3.254§ 0.001	2.670 2.455	0.100 141	2.148§ 0.033	6.577 5.000	0.513 140	3.075§ 0.003
Lack close relationship with instructors	0.753 1.159	0.282 141		0.856 1.273	0.179 141	−2.331§ 0.021	0.918 2.123	0.444 141	−2.491§ 0.014
Media will make learning more engaging	2.041 1.636	0.187 141	2.159§ 0.033	2.186 2.186	0.141 140		4.680 3.860	0.557 140	
Less prestige degree if earned at a distance	−0.845 −0.250	0.314 141		−0.784 −0.977	0.201 141		0.402 −0.045	0.511 141	
More expensive	−0.500 −0.205	0.273 140		−1.629 −1.932	0.204 141		1.219 0.295	0.619 140	
It takes a lot of self-discipline	2.010 2.295	0.214 141		2.490 2.364	0.157 140		5.375 5.659	0.638 140	

*Participants who listed a positive likelihood of intention to use distance education.
†Participants who listed a neutral or negative likelihood of intention to use distance education.
‡Items with missing data were excluded from the analysis.
§$p < 0.05$.
M_I = mean value of the intender group. M_{NI} = mean value of the non-intender group. MSE = mean square error. t = t statistic.

addressing life experience credit and the timing of courses. Courses were offered one night per week, for several hours, at regional sites.

In summary, 64% of respondents want, have, or are matriculating toward baccalaureate degrees. Degree seekers desired a broad range of degree majors. Eighty-three percent of the respondents wanted to begin matriculating within 5 years. Therefore, the respiratory care community should work toward creating access to the desired degree majors. Programs designed for practicing RTs should be offered at convenient times, close to home, and provide credit for prior life experience.

Distance education is one means to provide flexibility in the timing and location of study.[5,6] Respondents enrolled in baccalaureate degree programs and those who already completed a baccalaureate degree had little experience with distance education. A majority of those who want to pursue a baccalaureate degree had "slight" to "extremely likely" intentions to complete their degree through distance education. Conclusions about the merits of distance education baccalaureate respiratory care programs cannot be made until RTs gain more experience with and information about distance education.

The data relating to distance education showed that attitude and subjective social norm were the 2 variables that successfully predicted intentions in this study. These 2 variables explained a substantial amount (46%) of the variance. As demonstrated in the regression equation (Equation 4), attitude had more than twice as strong an influence on intention as the subjective social norm. Neither measure of subjective personal norm nor the perceived behavioral control variable achieved significance.

The subjective personal norm (moral obligation to obtain a baccalaureate degree) may not have been significant

Table 12. Comparison of Mean Subjective Social Norm Beliefs Between Intenders* and Non-Intenders†‡

	Referent beliefs (n_i)			Motivation to comply (mc_i)			Product ($n_i mc_i$)		
	M_I M_{NI}	MSE n	t p	M_I M_{NI}	MSE n	t p	M_I M_{NI}	MSE n	t p
Current employer	0.804	0.254	4.149§	4.227	0.283	2.245§	4.402	1.144	4.164§
	−0.250	141	< 0.001	3.591	141	0.026	−0.364	141	< 0.001
Potential future employer	0.557	0.213	2.285§	4.784	0.257		3.464	1.206	1.985§
	0.070	140	0.024	4.349	140		1.070	140	0.049
Family members	1.385	0.215	4.423§	5.072	0.242	1.986§	7.802	1.247	4.379§
	0.432	140	< 0.001	4.591	141	0.049	2.341	140	< 0.001
Friends	0.598	0.165	3.217§	3.918	0.207		2.701	0.787	2.797§
	0.069	141	0.002	3.659	141		0.500	141	0.006
Co-workers	0.649	0.183	3.423§	3.928	0.223		2.887	0.849	2.892§
	0.023	141	0.001	3.682	141		0.432	141	0.004

*Participants who listed a positive likelihood of using distance education.
†Participants who listed a neutral or negative likelihood of using distance education.
‡Items with missing data were excluded from the analysis.
§$p < 0.05$.
M_I = mean vlaue of the intender group. M_{NI} = mean value of the non-intender group. MSE = mean square error. t = t statistic.

for a few reasons. First, it may indicate that the respondents did not perceive obtaining a baccalaureate degree to be essential. Respondents voiced opinions that although a baccalaureate degree may be desirable, it is not perceived as an obligation. Changing the phrasing of this item from "moral obligation" to "obligation" to complete a baccalaureate degree might yield different results.

The lack of significance for the perceived behavioral control variable, on the other hand, could relate to the measure used for this variable. Principal components analysis on the 3 scale items for the perceived behavioral control score explained only 32% of the variance. A more reliable measure is needed to assess the perceived behavioral control's true role.

The moderate to high correlations between attitude/behavioral beliefs and subjective social norm/normative beliefs substantiated that the predictor variables and their corresponding beliefs measured the same construct. Thus, these beliefs probably explain the basis of respondents' attitudes and subjective social norms. However, this study's behavioral belief measure had a coefficient α of 0.29, which calls this scale's results into question. We applied the guidelines described by Ajzen and Fishbein in the development of the behavioral belief scale.[14] None of the item-total correlations stood out as being especially problematic. One explanation for the poor reliability might be the relative novelty of distance education to RTs. Some respondents commented that that they were not very familiar with distance education and that it was therefore difficult to answer some of the questions. Also, RTs currently seeking a baccalaureate degree had little experience with distance education.

The behavioral belief scale asked very specific questions about distance education. For example, it asked RTs to indicate whether they believed they would need to attend classes on campus or would have personal interactions with their classmates. The 2 scales with higher reliabilities (attitude and normative beliefs) asked more general types of questions. A couple of examples from these scales asked respondents to indicate what they thought their employer thinks about RTs completing a degree through distance education and how interesting or boring RTs find distance education courses. Asking specific questions about a novel topic might have affected the reliability measure and its correlation with attitude.

As expected, the results from beliefs that differentiated respondents likely to use distance education (intenders) from nonintenders showed that the intenders generally had more positive feelings toward each belief's outcome and gave a more positive evaluation of each belief. Intenders felt they would receive more prompt feedback from instructors, have more flexible class schedules, and develop a closer relationship with their instructors. Intenders were more likely to believe that, although they would be learning at a distance, they would retain more of the human elements involved in education.

It was curious that none of the behavioral belief comparisons related to distance education's prestige were significant. Both the intender and nonintender groups felt that completing a degree through distance education would *not*

have a low level of prestige. The concern about prestige was mentioned frequently by members of the convenience sample who developed the set of beliefs. Comments from respondents echoed this concern. For example, one respondent who already had a baccalaureate degree wrote:

> I do not believe in any type of distance or extended degree education . . . I think it would be a disservice to future employers and people who had a "real" baccalaureate degree . . . I have witnessed first hand the damage people with a "boughten" degree have done.

Perhaps changing the wording of this behavioral belief to measure distance education's legitimacy or credibility might measure the desired issue better. The prestige or legitimacy of distance education may have surfaced in the normative belief section instead. Intenders believed that their current employers, potential future employers, families, friends, and coworkers all were more supportive of completing a degree through distance education than did nonintenders. Several respondents wrote comments linking their concerns about prestige to their current employers:

> I would be willing to try any form of distance education . . . I only want to know that employers do value forms of education besides a university setting.

> It just felt "funny" doing correspondence school —questioning if it was a valid degree and how it would be received by employers.

Reevaluation of Behavioral Belief Measure

The low reliability score for the behavioral belief measure prompted us to further investigate this scale. First, the items within the highly-reliable attitude measure were correlated with the behavioral intention score. The highest correlation coefficients resulted for the pairs successful/unsuccessful (0.546), appropriate/inappropriate (0.524), practical/impractical (0.518), and interesting/boring (0.501). The next highest correlations involved the pairs useful/useless (0.458), nonthreatening/threatening (0.425), and creative/unimaginative (0.423). Because these adjective pairs represent affective measures and by nature are more general statements, there is no one-to-one correspondence between each pair and the behavioral beliefs. However, there should emerge general relationships between adjectives highly correlated with intentions and behavioral beliefs that differentiate intenders and nonintenders.

Next, the highly-correlated adjective pairs were compared to the behavioral beliefs that differentiated intenders from nonintenders. For example, "useful" can be associated with flexible schedules and prompt instructor feedback. Also, the use of media to make learning more engaging has links to "creative" and can be perceived as "nonthreatening" or, in some cases, "threatening."

Although behavioral beliefs provide greater specificity than the adjective pairs, evaluating the highly-correlating pairs brings to light some issues that might otherwise be overlooked. For example, the pair successful/unsuccessful had a high correlation and relates strongly to the ability of RTs to succeed in learning the course material. The members of the convenience sample did not address this topic. Related survey comments included the following:

> I completed my respiratory care degree via a distant program and found it very easy to complete. I also feel that the distant program is as effective as on-campus, as I was very well prepared for registry and the RPFT test.

> I received off-site education for CRTT 1984. Passed National Board of Respiratory Care board first time 1984. Percent of success from my experience and from studies show equal or better success rate for off-site first time passing of NBRC exam.

> I have already attempted California College registry program . . . When it got to sciences and mathematics I had extreme difficulty understanding and need an instructor in a classroom to complete.

> I wasn't sure if I could keep up on the studies on my own.

Clearly some of the respondents had prior experience with distance learning. Although some respondents in the convenience sample had experience with distance learning, the majority did not. A belief statement about successfully learning course content might emerge from a convenience sample that has more distance education experience.

A second theme that emerged from the adjective pairs and written comments was the accessibility of education. The adjectives "practical," "appropriate," and "useful" fit this theme. Related survey comments included:

> Ottawa University filled an important niche . . . This distance education method worked great for me. I finished in 2½ years while working full time. Recognition of current credits from RC program and flexible off campus teaching methods were the key for me choosing this program."

> I also strongly support off campus or distance education since for people in my situation it's a practical and reasonable way to obtain an education without the stress of schedules.

The greatest mean difference between intenders and nonintenders in the normative belief category dealt with the family's beliefs (see Table 12). Family commitment was a frequently-cited reason for not pursuing a baccalaureate degree or delaying the enrollment decision for a number of years. Interestingly, women made all of the written remarks about family time commitments. The relatively higher response rate from women in this study might be one of the reasons family commitments impacted so heavily in this study. This finding is consistent with the work cited earlier about women needing distance education as a means of decreasing role conflict and stress during their return to school.[3]

Our results have several implications for using distance education. First, potential enrollees need a clear understanding of how others, especially employers, value a degree through distance education. Written remarks and data from the normative belief section showed that the respondents were uncertain about how employers value a degree earned via distance education. The Distance Education and Training Council report found that employers were pleased with the performance of graduates who earned their degrees through distance education.[27] Sharing the views of employers who work with graduates of distance programs and conducting a survey of respiratory care managers would help RTs make better-informed decisions.

Because, for RTs, distance education is a relatively novel means of education, potential enrollees need access to more information on this topic. They need to know how to evaluate the institution providing the courses, the degree program and course work involved, quality of support services (technical and human), and cost.[28] It would also be helpful to know characteristics of students likely to succeed with distance education and how human factors are dealt with. For example, RTs need assurance that distance education programs can offer sufficient interaction between instructors, classmates, and course materials.

The literature on distance education is growing as more programs develop, so the effectiveness of distance education should become more apparent in time. A recent report from The Institute for Higher Education Policy amplifies that much of the research to date has focused on individual courses.[29] The impact of offering total educational programs at a distance has yet to be studied.

Specific to the field of respiratory care, offering entire educational programs through distance education might have different results, depending upon the learner's professional experience. The AARC's education consensus conferences focused on preprofessional training.[1,2] Although there was some support for using distance education for learners in underserved areas, it was not recommended for all preprofessional training.[2]

The use of distance education for respondents seeking baccalaureate degrees, graduate degrees, or continuing education has not been explored. It has been shown, however, that the amount of formal education positively correlates with successful completion of distance education courses or programs.[30] As a result, distance education may work better for practicing RTs. Further study of the impact of distance education within both preprofessional and postprofessional programs is needed to clarify these issues.

Distance education continues to change. The use of E-mail and other fast electronic means of communication has increased the speed of communication between instructors and students, and the proliferation of this technology, in both the workplace and home, provides good accessibility and fosters student-to-student interaction.[30] In addition to learning from one another, this fast communication has been shown to create a social presence among class members,[31] so in a well-structured distance course the student is not unduly isolated or deprived of educationally-valuable interaction with classmates.

Conclusions

The present study showed that almost half of the surveyed RTs who did not have a baccalaureate degree wanted one. Respondents wanted degree majors in business, administration, advanced practice, science, and teaching. The majority of RTs who earned degrees after being in the profession completed programs in management and administration. However, few had advanced practice or science degrees. The management and administration degrees were earned through completion of nontraditional programs that provided experiential credit and evening courses held once a week.

Most working RTs need nontraditional programs to complete their baccalaureate degrees. Respondents want access to a variety of degree majors, courses close to home, courses offered during weekday evening or weekend hours, and credit for prior learning.

Respondents indicated a moderate interest in distance education as a means to complete their baccalaureate degrees. The 2 variables that most strongly influenced their intentions were attitude and subjective social norm. The subjective personal norm variable and perceived behavioral control variable were not significant. The lack of significance with the subjective personal norm suggests that although many RTs desire baccalaureate degrees, they don't perceive them as essential.

The beliefs supporting the significant predictor variables showed that RTs who intend to use distance education feel they would get more instructor feedback, have a closer relationship with their instructor, and have more flexibility in their schedules than did nonintenders. General comments showed that RTs are concerned about the quality of education, their ability to succeed in course

work, and the value their employers place on a degree earned through distance education.

The relative novelty of distance education surfaced both in the written remarks and the quantitative analyses. RTs need detailed information about distance education and the characteristics of good distance education programs. Also, identifying respiratory care managers' beliefs about degrees earned through distance education will help inform RTs' decisions. Furthermore, additional research and information are needed to evaluate the application and success of distance education in respiratory care. Specifically, there is a need to look at how roles for distance education might differ between pre-professional and post-professional degree programs.

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Bronchodilator Resuscitation in the Emergency Department Part 1 of 2: Device Selection

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Introduction
Pressurized Metered-Dose Inhaler Versus Nebulizer
Technical Considerations – Pressurized Metered-Dose Inhaler
Spacers and Valved Holding Chambers
Nebulizers
Relationship of Deposition and Delivered Dose
Pressurized Metered-Dose Inhaler With Holding Chamber Versus Nebulizer – Adults
Asthma
Chronic Obstructive Pulmonary Disease
Combined Asthma and Chronic Obstructive Pulmonary Disease
Pressurized Metered-Dose Inhaler with Holding Chamber Versus Nebulizer – Children
Published Reviews and Meta-Analyses
Role of Ultrasonic Nebulizers
Dry Powder Inhalers and Breath-Actuated Inhalers
Effect of Positive-Pressure Breathing
Device Selection
Myths or Facts
Patient Education and Empowerment
Staff Knowledge
Cost

Summary [Respir Care 1999;44(11):1353–1374] *Key words: bronchodilator resuscitation, emergency department, pressurized metered-dose inhaler, holding chamber, nebulizer, acute airway obstruction, aerosol therapy.*

Introduction

Asthma and chronic obstructive pulmonary disease (COPD) are widely prevalent in the United States, affecting up to 11% of the population.[1] Patients suffering acute exacerbations of asthma or COPD commonly seek medical assistance in the emergency department (ED). This review examines bronchodilator resuscitation in the ED for symptomatic relief of acute airway obstruction.

Most patients presenting to the ED with acute asthma or COPD have had worsening symptoms for 24–36 hours. They have typically been self-administering whatever relevant medications they have, at greater than prescribed dose and frequency, with little or no effect. The patient is usually uncomfortable, tired, frustrated, and scared. The first order of business for these patients is to relieve the airway obstruction, reduce the work of breathing, and decrease the patient's feeling of panic. Treatment in the ED commonly includes administration of systemic corticosteroids and aerosolized bronchodilators.[2] The onset of action for steroids, whether given intravenously or orally, occurs

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after 45 minutes, with several hours required for measurable bronchodilator effect. The role of bronchodilator resuscitation is to provide symptomatic relief while waiting for the corticosteroids to reduce airway obstruction.

A careful review of the literature reveals that there are several key components regarding bronchodilator resuscitation in the ED. These components include selection of appropriate device, continuous versus intermittent administration of aerosol, high or low dosing strategies, and the use of beta-2 adrenergic agonists alone, or in combination with anticholinergic bronchodilators. In addition, the severity and the intrinsic reversibility of airway obstruction among patients influence the response to treatment.

The literature abounds with research and opinions about aerosol delivery devices,[3] medications, and dosing strategies available for use in the ED to provide symptomatic relief of severe airway obstruction. Despite an impressive amount of literature showing that the pressurized metered-dose inhaler with holding chamber (pMDI/HC) is as effective and efficient, and less costly,[5–12] many practitioners prefer the use of the nebulizer for bronchodilator delivery in the ED.[4]

In the first part of this review, we examine the impact of device selection on bronchodilator resuscitation. Review of the role of continuous versus intermittent nebulization, dosing strategies, and use of anticholinergics will appear in a subsequent issue of RESPIRATORY CARE.

Pressurized Metered-Dose Inhaler Versus Nebulizer

Although the pMDI is the most commonly prescribed aerosol device for patients at home, a bias toward the use of nebulizers in the ED persists. This may be due, in part, to common patient complaints that the use of pMDIs prior to presenting to the ED (after having self-administered more puffs than prescribed) failed to provide adequate relief. In addition, numerous reports in the literature document problems with patient use and a lack of practitioner understanding of proper technique for use of pMDIs.[13] The limitation of the pMDI is well documented, requiring considerable hand-breath coordination and breath control for optimal therapy, which is difficult for many patients, especially during acute exacerbations. Even patients who demonstrate proper pMDI technique when their dyspnea is under control may not properly self-administer with a pMDI when acutely short of breath.

With this in mind, we present a brief review of salient technical considerations for appropriate use of pMDIs, holding chambers, and pneumatic nebulizers.

Technical Considerations – Pressurized Metered-Dose Inhaler

The pMDI canister contains a pressurized mixture of propellants, surfactants, preservatives, and flavoring agents, with approximately 1% of the total contents being active drug.[14] This mixture is released from the canister through a metering valve and stem, which fits into an actuator boot, designed and tested by the manufacturer to work with that specific formulation. Small changes in actuator design can change the characteristics and output of the aerosol from a pMDI. Whenever a pMDI is being used with an actuator other than the one supplied by the manufacturer, in vitro testing should be performed to determine performance characteristics of the new combination.[15] The output volume of the pMDI varies from 30 to 100 μl and contains between 20 μg and 5 mg of drug, depending on formulation. Lung deposition is estimated at between 10% and 25% in adults, with high intersubject variability, largely dependent on user technique.[16–18] When proper technique or an effective accessory device (ie, holding chamber) is used, the pMDI delivers a substantially greater proportion of the nominal dose to the lung than a pneumatic nebulizer.[14]

Table 1. Optimal Technique for Using a Pressurized Metered-Dose Inhaler (Bronchodilator Only)

1. Warm pressurized metered-dose inhaler (pMDI) canister to hand or body temperature, shake vigorously.
2. Assemble apparatus, uncap mouthpiece, and make sure there are no loose objects in device.
3. Open mouth wide, keep tongue from obstructing the mouthpiece.
4. Hold the pMDI vertically, with the outlet aimed at mouth.
5. Place canister outlet between lips, or position the pMDI about 4 cm (two fingers) away from mouth.
6. Breathe out normally.
7. As you begin to breathe in slowly (< 0.5 L/s); actuate (fire) the pMDI.
8. Continue to inhale to total lung capacity.
9. Hold breath for up to 10 seconds.
10. Wait 30 seconds between inhalations (actuations).
11. Disassemble apparatus and recap mouthpiece.

Effective use of the pMDI is technique-dependent. Up to two thirds of patients who use pMDIs *and* health professionals who teach pMDI use do not perform the procedure properly.[19,20] Table 1 details recommended steps for administering a bronchodilator using a pMDI.[21,22]

Common hand-breath coordination problems include actuating the pMDI before or after the breath.[13,19,20] Some patients, especially infants, young children, the elderly, and patients in acute distress may simply not be able to use a pMDI. In addition, some patients perceive a "cold FREON effect" that occurs when the aerosol plume reaches the back of the mouth, and the patient stops inhaling. All of these problems reduce aerosol delivery to the lung, but can be corrected in part or whole by using the proper pMDI accessory device.

Table 2. Optimal Technique for Using a Pressurized Metered-Dose Inhaler With a Valved Holding Chamber

1. Warm pressurized metered-dose inhaler (pMDI) canister to hand or body temperature.
2. Assemble apparatus and make sure there are no objects in device that could be aspirated or obstruct the flow.
3. Shake canister vigorously and hold canister vertically.
4. Place holding chamber in mouth (or place mask completely over nose and mouth), encouraging patient to breath through mouth.
5. Breath normally and actuate (fire) pMDI at the beginning of inspiration; for small children and infants, continue to breathe through the device for 5 or 6 breaths. Larger breaths with breath-holding may be encouraged in those patients who can cooperate.
6. Allow 30 seconds between actuations.

Spacers and Valved Holding Chambers

The key to successful use of the pMDI in the ED appears to be the use of a holding chamber. Holding chambers range from 130 to 750 mL, with sufficient internal volume to allow the plume of the pMDI to expand, allowing time for the propellants, solvents, and other ingredients to evaporate, increasing the percentage of respirable mass available to the patient. Holding chambers have been shown to improve pulmonary deposition from approximately 10% (with pMDI alone) to $\geq$ 20%.[18] Placement of a valve between the chamber and the patient serves as a baffle impacting large aerosol particles that would otherwise deposit in the oropharynx (reducing oral deposition from 80% to less than 1% of the nominal dose), decreasing the total body dose from swallowed medication. The valve also redirects exhaled gas so that aerosol remaining in the chamber is not "blown away" on exhalation. A patient with a small tidal volume may empty the aerosol from the chamber with 5–6 breaths. A valved holding chamber can also incorporate a mask for use with infants or children. These devices allow effective pMDI administration to patients who are unable to use a mouthpiece because of size, age, coordination, or mental status.[23–30] For use with infants it is critical that these masks should have minimal dead space, be comfortable for the child's face, and the chamber must have a valve that will open or close with low inspiratory flow. Table 2 details optimal technique for using a pMDI with a valved holding chamber.

While the use of valved holding chambers offers significant advantages in administration compared to the pMDI alone, no device is foolproof. Table 3 summarizes common problems in self-administration with pMDIs and pMDIs with holding chambers. Holding chambers have proven to be the "great equalizer" between pMDIs and nebulizers. Consequently, over the past decade virtually all of the randomized controlled trials comparing the use of pMDIs and nebulizers for treatment of acute, severe asthma in the ED have used pMDIs with valved holding chambers (Fig 1).[12]

Nebulizers

Nebulizer selection affects aerosol delivery. Only nebulizers that have been shown to work reliably under specific conditions with specific medications should be used. Nebulizers producing aerosols with mass median aerodynamic diameter of 1–3 μm are more likely to achieve greater deposition in the lower respiratory tract.[14] European standards specify that an effective pneumatic nebulizer should deliver > 50% of its total dose as aerosol in the respirable range mass median aerodynamic diameter (1–5 μm) in $\leq$ 10 minutes of nebulization time. Nebulizer performance varies with diluent volume, operating flow, operating pressure, gas density, and nebulizer model.[31–34] The amount and percentage of drug nebulized increases as the volume of diluent is increased. The residual volume of medicine that remains in commercial small-volume nebulizers varies from 0.5 to 1.5 mL, depending on the device, so increasing the fill volume allows a greater proportion of the active medication to be nebulized. However, to date no significant difference in clinical response has been shown with varying diluent volumes and flow rates.[33]

With so much medication left in the nebulizer, when should the standard nebulizer treatment end? Malone et al found that with 3 different fill volumes, albuterol delivery from the nebulizer ceased following the onset of inconsistent nebulization (sputtering).[35] Aerosol output declined by half within 20 seconds of the onset of sputtering. The concentration of albuterol in the nebulizer cup increased significantly once the aerosol output declined, and further weight loss in the nebulizer was primarily due to evaporation. The authors concluded that aerosolization past the point of initial jet nebulizer sputter is ineffective.

Relationship of Deposition and Delivered Dose

Lewis and Fleming[36] assessed fractional deposition of aerosol from a nebulizer by having 6 normal and 2 asthmatic subjects inhale aerosol of technetium from a jet nebulizer. They reported that 66% of the nominal dose remained in the nebulizer, while 2% deposited in the mouth, 20% was exhaled, and 12% was deposited in the lung. This is markedly different from the findings of Newman et al[16] in their study of the use of pMDI alone. They found that 9% deposited in the lung, 80% in the oropharynx, 10% in the apparatus, and approximately 1% was exhaled. Subsequent studies using pMDI/HCs showed a reduction in oropharyngeal deposition, to as low as 1%, with 78% of the nominal dose remaining in the chamber, and 20–25% being delivered to the lungs (Fig 2).

Albuterol, like most beta-2 adrenergic bronchodilators, has a log dose response (Fig 3).[37] There is an initial steep response to the bronchodilator at relatively low doses, and as the dose is increased the response flattens but continues

Table 3. Comparison of Errors Associated With the Use of Pressurized Metered-Dose Inhalers and Pressurized Metered-Dose Inhalers with Holding Chambers

Pressurized Metered-Dose Inhaler with Holding Chamber	Pressurized Metered-Dose Inhaler
Major Errors	
Inability to trigger MDI	Inability to trigger MDI
Inability to attach MDI	MDI actuated after inhalation
Failure to inhale through device	MDI actuated during exhalation
	MDI actuation stops inhalation (cold FREON effect)
	Multiple actions during single breath
	Failure to inhale through device
	Failure to remove MDI cap
Minor Errors	
Difficulty with attaching MDI	Triggering MDI late, but during inhalation
Rapid repetitive actuation of MDI	Failure to hold breath after inhalation
Failure to shake MDI	Failure to shake MDI

(Adapted from Reference 13.)

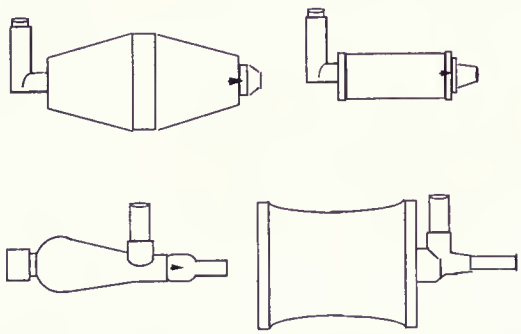

Fig. 1. Examples of valved holding chambers used with pressurized metered-dose inhalers in randomized clinical trials published in the last 12 years. Ranging from 140–750 mL in volume, each device utilizes a one-way valve (designated by the arrow) placed between the holding chamber and the patient's airway.

to improve. The United States Food and Drug Administration's approved standard dose for albuterol via pMDI is 200 μg, while the standard dose with albuterol sulfate solution is 2.5 mg (2,500 μg). Pulmonary deposition of albuterol, eliciting $\geq$ 10% improvement in the forced expiratory volume in the first second (FEV_1) or peak expiratory flow (PEF) in stable asthmatics is $\approx$ 20 μg with a pMDI and 250–300 μg with a nebulizer. Consequently, the nebulizer delivers more than 10–15 fold more albuterol to the lung than would be required to provide bronchodilation with the pMDI. Use of a holding chamber has been shown to increase pulmonary deposition to 20–25%, representing a $\geq$ 40 μg dose of albuterol to the lungs while reducing oral deposition by 158 μg, substantially reducing the extrapulmonary systemic dose to the patient, reducing the incidence of adverse effects. In small children and infants, deposition can be less than 1%, representing less than 25 μg delivered to the lung from the nebulizer.

Pressurized Metered-Dose Inhaler with Holding Chamber Versus Nebulizer – Adults

Randomized, controlled clinical studies comparing the use of pMDI/HCs and pneumatic nebulizers for bronchodilator resuscitation have proliferated over the past decade. To provide greater insight into their findings, we begin with a review of the subset of studies of adult patients presenting to the ED with exacerbation of asthma, COPD, or a combination thereof.

Asthma

Salzman et al[38] studied bronchodilator response to metaproterenol delivered via pMDI/HC and nebulizer in 44 asthmatic patients who presented to the ED with acute severe airflow obstruction (FEV_1 < 50% of predicted). The delivery method was randomized, double-blind, and placebo controlled. The pMDI/HC group received 1 puff of metaproterenol every 5 minutes for a total of 3 puffs (1.95 mg) and the nebulizer group received 15 mg of metaproterenol over 10 minutes. The mean percentage improvement in forced vital capacity (FVC) and FEV_1 trended higher (33.5% and 49.0%, respectively) in the pMDI/HC group than the nebulizer group (22.8 and 33.0%, respectively) but was not statistically significant.[38]

In 1993, Colacone et al[39] reported a randomized, double-blind, placebo-controlled trial of 80 adults presenting to the ED with acute severe asthma (FEV_1 36% of pre-

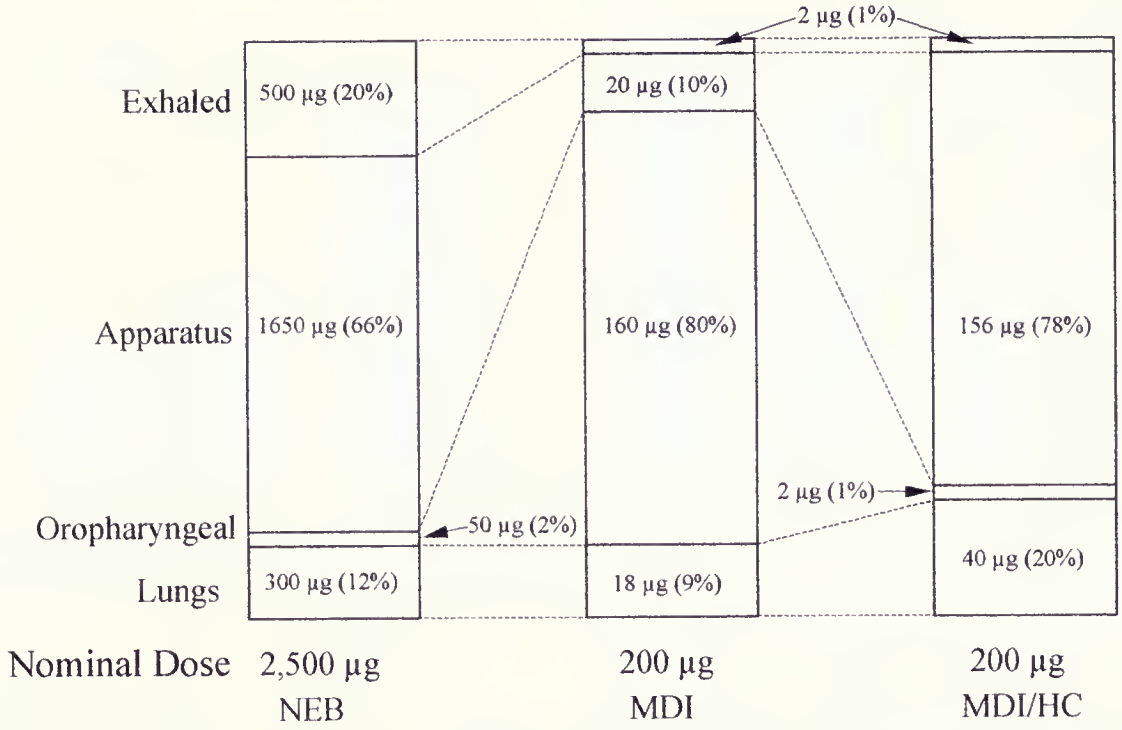

Fig. 2. Analysis of the deposition from a pneumatic nebulizer (NEB) (left), a pressurized metered-dose inhaler (MDI) (center) and a pressurized metered-dose inhaler with holding chamber (MDI/HC) (right), showing the amounts and percents of the nominal albuterol dose deposited in the lungs, oropharynx, apparatus, and exhaled. (Adapted from References 16 and 36.)

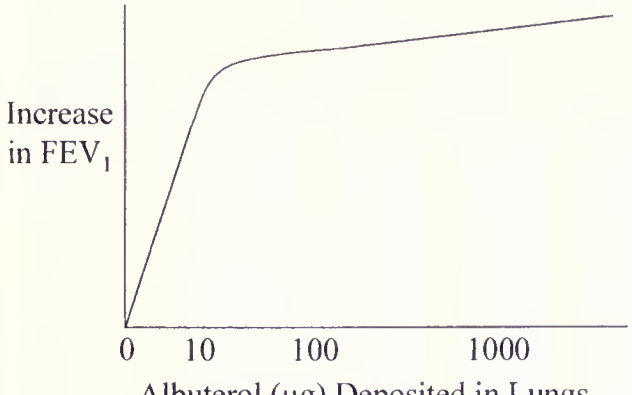

Fig. 3. Conceptual representation of the shallow bronchodilator response curves to albuterol in stable asthmatics. There are 2 phases of response, with the majority of response occurring after lung deposition of 10–20 μg of albuterol in the lung. In Phase 2 the response to increasing lung dose of albuterol is less steep.

dicted). Patients received albuterol via pMDI/HC (0.4 mg) or nebulizer (2.5 mg) every 30 minutes until maximal bronchodilation (Fig 4). Most of the pMDI/HC group (65%) and nebulizer group (75%) achieved maximal bronchodilation after 2 doses, with virtually all patients in both groups reaching maximal bronchodilation by 4 doses. The FEV_1 improved by 0.72 ± 0.49 L for the pMDI/HC group and 0.68 ± 0.61 L for nebulizer group ($p = 0.71$). A significant linear relationship ($r = 0.94$) was found in both groups between the log dose of albuterol and the change in FEV_1.[39] About one sixth of the nebulizer dose of albuterol achieved similar response with the pMDI/HC.

Idris et al[40] reported a randomized, double-blind, placebo-controlled study of 35 patients, age 10–45 years, with $FEV_1 < 40\%$ of predicted, in the ED for acute asthma exacerbation. Patients received albuterol or placebo via pMDI/HC (360 μg) or nebulizer (2.5 mg) every 30 minutes until FEV_1 was 80% of predicted or 6 doses had been given. Mean FEV_1 improved for both groups at 30 minutes ($p < 0.02$) and at 60 minutes ($p < 0.02$), as did maximum mean FEV_1 ($p < 0.001$), which occurred at a mean 92 ± 50 minutes (Fig 5). No differences were observed between the groups ($p < 0.6$), but the time required to administer pMDI/HC (6 minutes first treatment, and 3 minutes for each of the subsequent 6 treatments) was less than the nebulizer (10–15 minutes per treatment). Thirty-three of 35 patients were treated successfully with the study protocol, became asymptomatic, and were discharged home. One patient from each group required further treatment. There was no detectable difference in effectiveness of albuterol administered via nebulizer or pMDI/HC when the dose was titrated to clinical response.

Rodrigo and Rodrigo[41] selected albuterol doses calculated on the basis of the percentage of total dose that

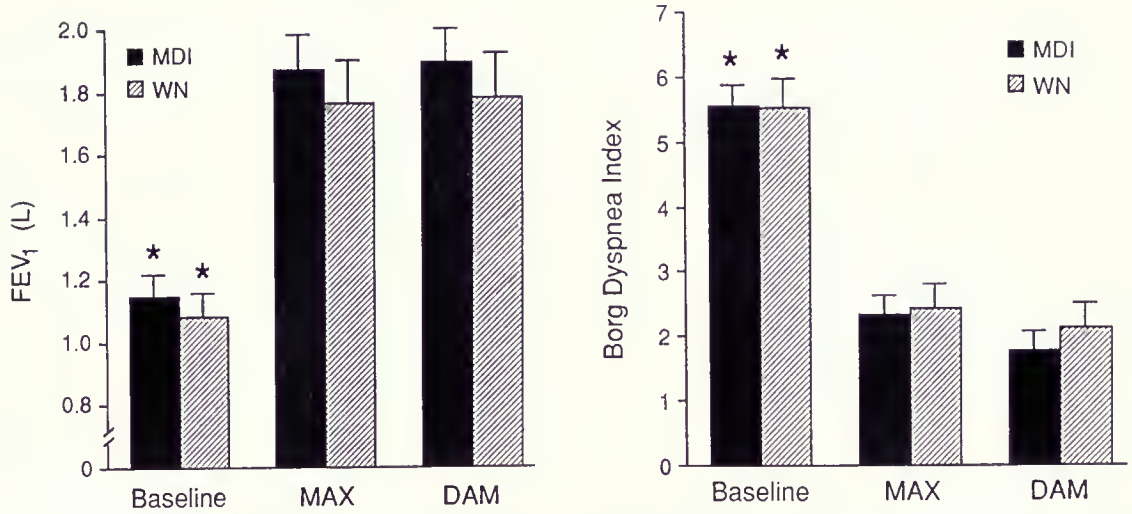

Fig. 4. Mean forced expiratory volume in the first second (FEV_1) (± standard of the mean) and Borg Score were similar for patients treated with albuterol delivered via pressurized metered-dose inhaler and via wet nebulizer (WN) at baseline, maximal bronchodilation (MAX), and one dose above maximal bronchodilation (DAM). Both groups showed significant improvement at MAX and DAM compared to baseline values. (From Reference 39, with permission.)

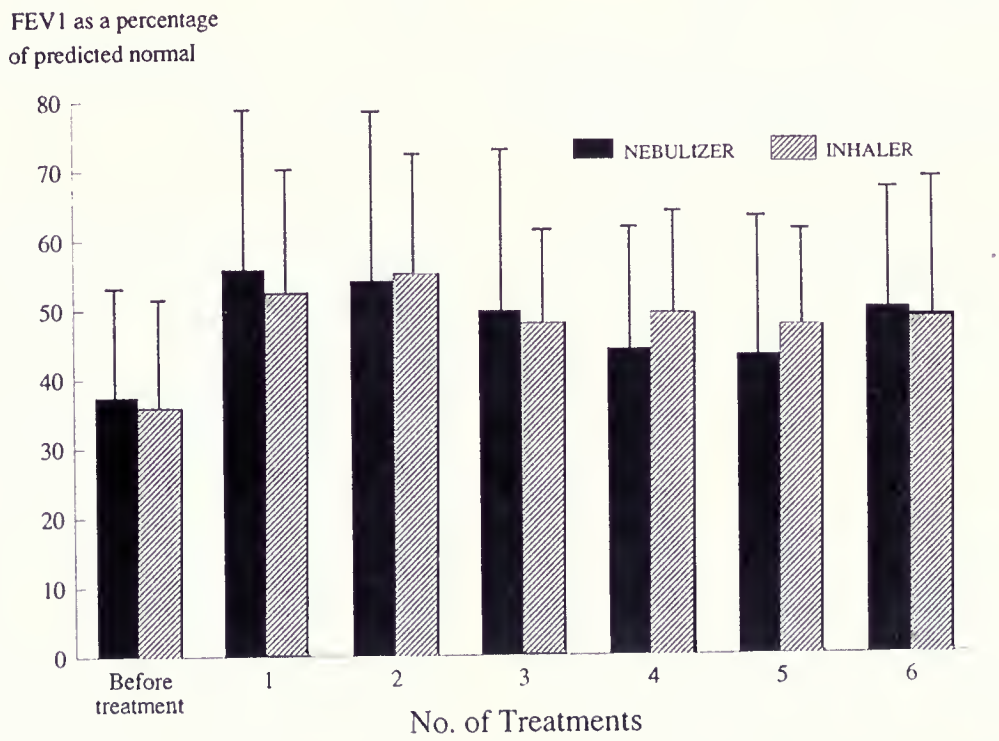

Fig. 5. Percent of predicted forced expiratory volume in the first second (FEV_1) in acute asthmatic patients given albuterol via nebulizer (2.5 mg per treatment) and via pressurized metered-dose inhaler with holding chamber (inhaler) (360 μg per treatment) at 30-minute intervals. Both groups improved from baseline, with no statistical difference between groups. (From Reference 40, with permission.)

reaches the lower airways with nebulizer (10%) and pMDI/HC (20%). Ninety-seven patients, age 18–50 years, with acute bronchial asthma previously treated at a hospital ED were enrolled in this randomized, double-blind, placebo-controlled trial, receiving albuterol via pMDI/HC (400 μg at 10-minute intervals) or nebulizer (1.5 mg at 15-minute intervals) over a 3-hour period. The final mean dose was 5.61 mg for the pMDI/HC group and 11.8 mg for the nebulizer group (2:1 dose ratio). Both groups improved from baseline, with no difference in response, ED treatment

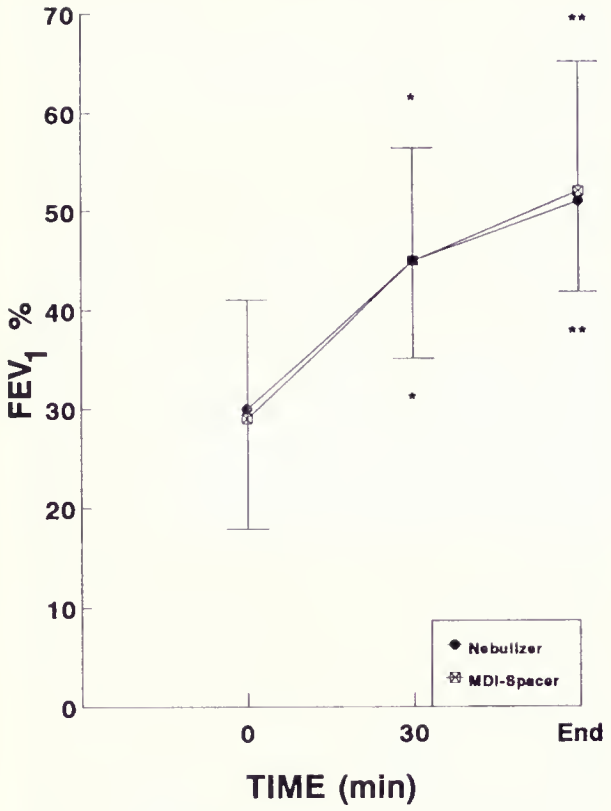

Fig. 6. Percent of predicted forced expiratory volume in the first second (FEV_1) at baseline, 30 minutes, and end of treatment for 97 patients with severe asthma, randomized to receive albuterol via pressurized metered-dose inhaler with holding chamber (MDI) (400 μg at 10-minute intervals) or nebulizer (1.5 mg, at 15-minute intervals) over a 3-hour period. The final mean dose was 5.61 mg for the MDI group and 11.8 mg for the nebulizer group (2:1 dose ratio). Both groups improved from baseline, with no difference between groups. * $p < 0.01$. ** $p < 0.001$. (From Reference 41, with permission.)

time, or admission rate (Fig 6). Similar patterns were seen in patients with severe airway obstruction ($FEV_1 < 0.9$ L). Both the pMDI/HC and nebulizer regimens provided similar rates of spirometric and clinical improvement.

Rodrigo and Rodrigo[42] reported a randomized, double-blind, parallel group study of ED patients suffering severe asthma exacerbation ($FEV_1 < 50\%$ of predicted).[34] The pMDI/HC group received 400 μg of albuterol at 10-minute intervals (2.4 mg/h), while the nebulizer group received 1.5 mg of albuterol sulfate at 15-minute intervals (6 mg/h) over 3 hours. PEF and FEV_1 improved significantly over baseline for both groups ($p = 0.01$). There was no difference between either group at any time studied. They found a significant linear relationship between cummulative dose and FEV_1 for pMDI and nebulizer ($r = 0.97$ for both). Regression equations showed that for every 1 mg of salbutamol via pMDI/HC, 2.5 mg were needed via nebulizer for equal therapeutic response. At the end of treatment, plasma albuterol levels were 10.1 ± 1.6 ng/mL for the pMDI/HC group and 14.4 ± 2.3 ng/mL for the nebulizer group ($p = 0.0003$). The larger systemic absorption of albuterol by the nebulizer group may account for the higher incidence of tremor ($p = 0.03$) and anxiety ($p = 0.04$) experienced. The authors concluded that when the dose of albuterol is calculated on the basis of the percentage of total drug that reaches the lower airway from each device, there was equivalent bronchodilation with either pMDI/HC or nebulizer in patients with acute severe asthma.

In 1994, Robertson[43] performed a dose-response study of albuterol via pMDI/HC and nebulizer, concluding that the metered-dose inhaler is as rapid and efficacious as the nebulizer in the treatment of acute asthma.

Chronic Obstructive Pulmonary Disease

In 1987, Jasper et al[5] compared aerosol bronchodilator delivery with metaproterenol administered every 4 hours via pMDI/HC or nebulizer in 34 patients hospitalized with obstructive airway diseases, enrolled after transfer to the pulmonary ward from the ED or intensive care unit. Daily spirometry indicated that both treatment groups had equivalent bronchodilation initially and equivalent improvement at discharge. The duration of hospitalization for the 2 groups was also the same. The authors reported that in one year, 3,680 patients received a total of 47,038 aerosol treatments, with 16,495 nebulizers. The costs of nebulizers ($1.00 each), medication ($0.07), and labor ($5.94 per treatment) totalled $299,193. Use of pMDI/HCs represented a one-time cost per admission of $12.42 (instruction time, holding chamber, and pMDI). They calculated that use of pMDI/HCs rather than nebulizers with adult patients would save their institution $253,487 per year in labor costs.[5]

Summer et al[6] studied 36 acutely ill, hospitalized adult patients with acute exacerbation of obstructive airway disease who showed a < 10% increase in FEV_1 after administration of aerosolized bronchodilator. Patients were randomized to receive either a standard dose of metaproterenol sulfate via nebulizer or terbutaline sulfate via pMDI/HC. The changes in FEV_1 and length of stay with pMDI/HC were at least equivalent to changes with nebulizer, with a lower daily charge for therapy and less respiratory therapist time.[6]

Combined Asthma and Chronic Obstructive Pulmonary Disease

In 1988, Turner et al[44] compared the efficacy of nebulizers and pMDI/HCs in 75 randomly assigned patients (22 COPD and 53 asthma) treated in double-blind fashion with 3 puffs of metaproterenol (0.65 mg/puff) via pMDI/HC plus nebulizer with placebo, or placebo pMDI/HC plus

nebulizer with 15 mg metaproterenol. Either treatment was given 3 times at 30-minute intervals. The FEV_1 and dyspnea scores (using Borg scale) showed no significant outcome difference between the two treatments in either diagnostic group. There was no outcome difference for patients with baseline $FEV_1 < 0.9$ L.[44]

Levitt, Gambrioli, and Fink[45] conducted a randomized, double-blind, placebo-controlled study of 40 adult patients in the ED with acute exacerbation of COPD or asthma ($FEV_1 < 30\%$ of predicted). Over a 3-hour period patients received continuous nebulization with 15 mg per hour albuterol or normal saline via large-volume nebulizer and intermittent treatment of up to 24 puffs per hour with 2.4 mg/h of albuterol or placebo via pMDI/HC. Both groups had significant improvements in FEV_1, PEF, and Borg score, with no difference between groups, and no incidence of tremor or tachycardia that necessitated discontinuing therapy. Most patients had 100% improvement from baseline of peak flow or FEV_1/FVC (Fig. 7). Many patients in the pMDI/HC group had maximum response with the first 12 puffs (1200 μg). Approximately 66% of each group were discharged from the ED at or before 3 hours, without relapse in 72 hours. No patients required intubation or mechanical ventilation for their asthma.

In 1997, Mandelberg et al[46] reported results of a randomized, double-blind, placebo-controlled study of 50 adult patients with severe acute obstructive pulmonary event (13 COPD, 37 asthma) with $FEV_1 < 32\%$ of predicted.[28] The pMDI/HC group received 200 μg of albuterol or placebo and the nebulizer group received 2.5 mg of albuterol or saline solution, repeated 3 times at 15-minute intervals, unless adverse effects appeared. Both groups had significant improvement from baseline, with no difference in spirometry measurements between the two groups at any time (Fig 8). This study demonstrated that with an unselected group of patient referrals to the ED for episodes of severe airflow limitation, clinical and the objective bronchodilator response to albuterol is independent of the method of delivery.

In summary, pMDI/HCs are at least as effective as nebulizers for administration of beta agonist bronchodilators to adult asthmatic and COPD patients presenting to the ED with moderate to severe airway obstruction (see Table 4).

Pressurized Metered-Dose Inhaler With Holding Chamber Versus Nebulizer – Children

In 1986, Fuglsang et al[47] studied 21 asthmatic children, age 7–14 years, presenting to the ED with a mean FEV_1 of 29% of predicted. The children were randomly assigned to receive a 1.0 mg/kg dose of terbutaline via pMDI/HC (Nebuhaler*) or nebulizer. Both groups had improvement from baseline, but the pMDI/HC group had a significantly greater increase in FEV_1 than the nebulizer group ($p < 0.05$). A majority of the children expressed a preference for the pMDI/HC over the nebulizer, because of the shorter administration time.

Kerem et al[48] conducted a double-blind, placebo-controlled study of 33 children, age 6–14 years, seen in the ED with acute asthma and FEV_1 between 20% and 70% of predicted. Patients received albuterol and placebo via pMDI/HC and nebulizer with a dose ratio of 1:5. With the exception of heart rate, which increased in the nebulizer group and decreased in the pMDI/HC group ($p < 0.05$), no difference in the rate of improvement of clinical score, respiratory rate, arterial oxygen saturation, or FEV_1 was observed between the groups during the 40-minute study period.

In 1995, Lin and Hsieh studied 111 children suffering acute asthma treated with terbutaline via pMDI/HC (0.75 mg) versus nebulizer (5 mg).[49] The pMDI/HC group had better oxygen saturation, better absolute increase of PEF (32.6 L/min vs 10.1 L/min), and better FEV_1 percent increase (22.9% vs 15.4%, respectively). The authors noted that desaturation during acute asthma is a risk when the nebulizer is operated with an air compressor.

Parkin et al[50] studied 60 hospitalized asthmatic children, age 1–5 years, randomized to receive pMDI/HC (400–600 μg albuterol with 40 μg ipratropium) or nebulizer (0.15 mg/kg albuterol and 400 μg ipratropium bromide). A clinical score was measured at baseline (pMDI/HC 5.7 vs nebulizer 4.8, $p = 0.02$) and every 12 hours. Both groups had significant improvement, with no differences between groups in the score over time or secondary outcome measures (Fig 9).

Similarly, Chou, Cunningham, and Crain studied 152 children, age 2 years and older, presenting to the ED with acute asthma exacerbation (mean PEF 53–56% of predicted).[51] The children were randomly assigned to receive albuterol via pMDI/HC (180–360 μg) or nebulizer (2.5–5 mg) at 20-minute intervals. There were no significant differences between the groups in outcomes, including mean change in respiratory rate, asthma severity score, PEF, oxygen saturation, number of treatments given, administration of steroids in the ED, or admission rate. However, the pMDI/HC group required shorter treatment times in the ED than did the nebulizer group (66 minutes vs 103 minutes, $p < 0.001$), while patients in the nebulizer group had more episodes of vomiting in the ED (20% vs 9%, $p < 0.04$) and greater mean percent increase in heart rate (15% vs 5%, $p < 0.001$).

*Suppliers of commercial products are identified in the Product Sources section at the end of the text.

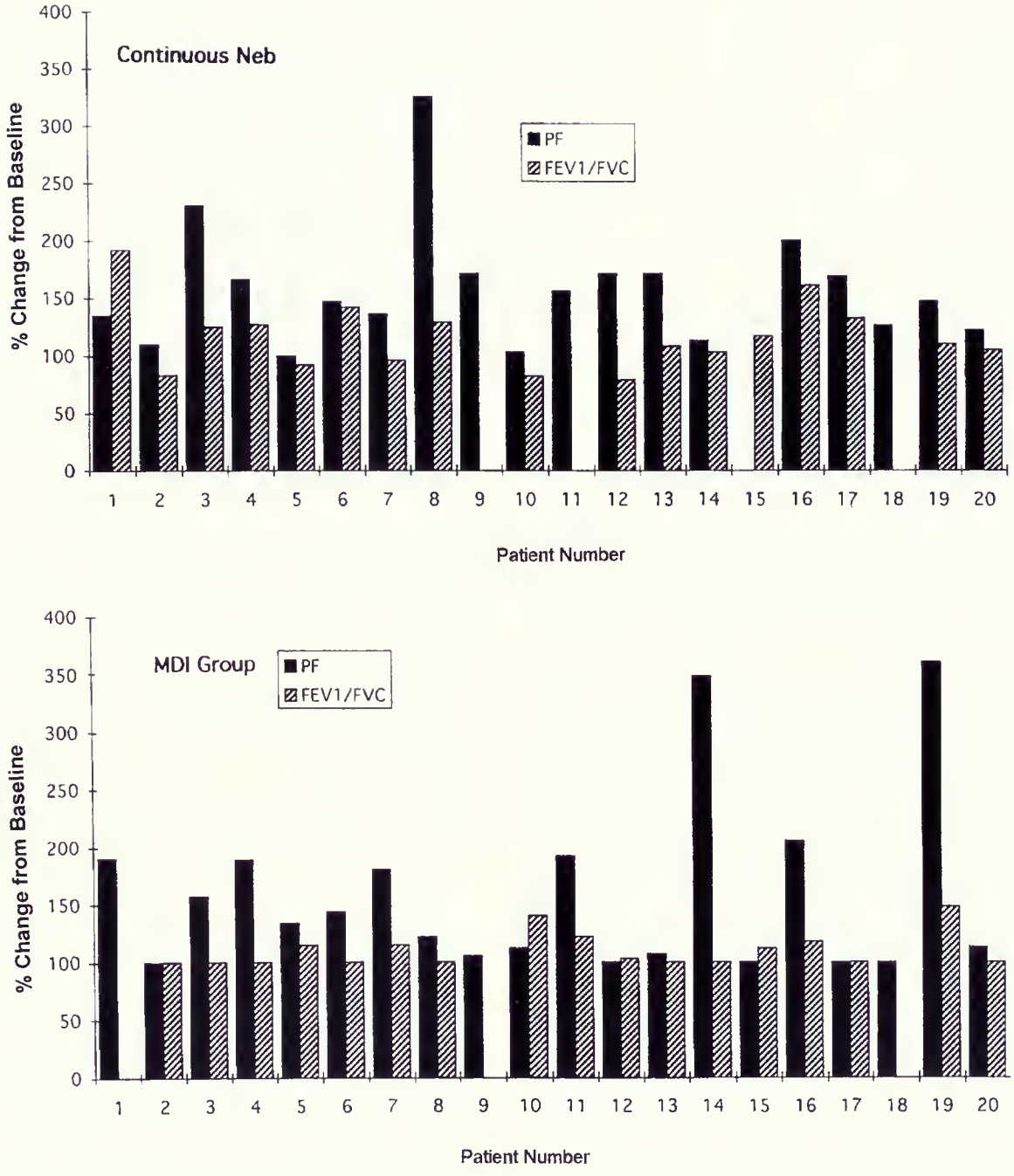

Fig. 7. Change from baseline in the ratio of the forced expiratory volume in the first second to the forced vital capacity (FEV_1/FVC) and peak flow (PF) for patients with severe asthma or chronic obstructive pulmonary disease treated with albuterol via continuous nebulizer (Neb) (15 mg/h) (upper histogram) or pressurized metered-dose inhaler with holding chamber (MDI) (lower histogram) (2.4 mg/h) over a 3-hour period.[45] (Modified from Reference 93, with permission.)

In 1996, Williams et al[52] randomized 60 children with acute asthma exacerbation (mean PEF 46% ± 20% percent of predicted) who had not had corticosteroid administration within the preceding 7 days. Children received either nebulizer or one of two pMDI/HC treatment groups (two spacers were evaluated). The dose ratio for albuterol via nebulizer (2.5 mg per treatment) versus pMDI/HC (360 μg) was 6.9:1, and 3 treatments were administered evenly over 1 hour. All groups improved following albuterol therapy in both PEF percent of predicted and respiratory rate, with no significant difference between the 3 treatment groups.

Batra et al[53] studied 60 children, age 1–12 years, suffering acute asthma, randomized to receive albuterol via

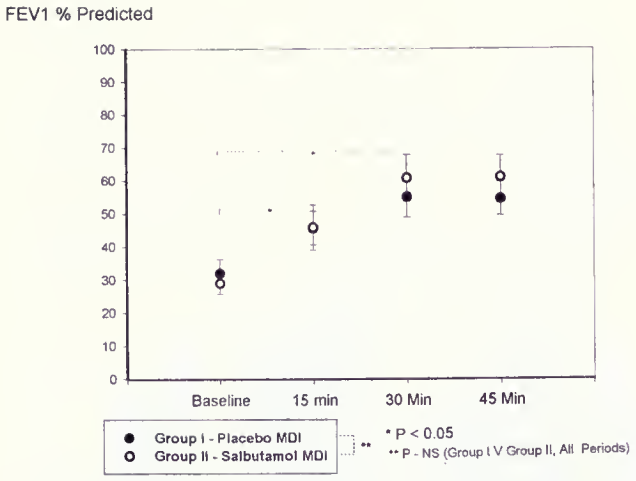

Fig. 8. Percent of predicted forced expiratory volume in the first second (FEV_1) (mean ± standard error) at baseline and after each intervention. The nebulizer group (Group I) received 2.5 mg of albuterol or saline solution, and the inhaler group (Group II) received 200 μg of albuterol or placebo. All treatments were repeated 3 times at 15-minute intervals, unless adverse effects appeared. Both groups had significant improvement from baseline, with no difference in spirometric measurements between the two groups at any time. (From Reference 46, with permission.)

nebulizer or pMDI/HC. A greater number of subjects in the pMDI/HC group ($p < 0.02$) presented with severe dyspnea and intercostal muscle retraction (subjective assessment) at baseline, but the objectively-evaluable outcome parameters were comparable ($p < 0.05$) in both groups. All the outcome measures showed a significant ($p < 0.05$) improvement in both the groups, with comparable recovery parameters ($p < 0.05$) at different time periods. These authors pointed out that for developing countries, distinct advantages (economic and power requirement) argue strongly for utilization of pMDI/HCs in preference to nebulizers.

Robertson et al[54] reported in 1998 on a multicenter ($n = 5$), double-blind, randomized study of 160 children, age 4–12 years, that compared albuterol administration via pMDI/HC and nebulizer. Children ≤ 25 kg received 2.5 mg albuterol via nebulizer or 600 μg via pMDI/HC, while children over 25 kg received 5 mg or 1200 μg (12 puffs). There was improvement in severity score and peak flow in both groups, but greater with the nebulizer than the pMDI/HC. A complicating factor in this study was the procedure of firing 3 puffs of albuterol from the pMDI into the holding chamber in rapid succession while the patient breathed tidally for 15 seconds. Rapid actuation of the pMDI dramatically reduces the output of the pMDI, and loading the holding chamber with multiple actuations can reduce aerosol available to the patient by another 65%.[55] Unfortunately, this methodologic complication in delivery technique obscured other factors of interest such as the use of tidal breathing and dose distinctions by weight. James and Masters[56] had previously found no difference in bronchodilator response in asthmatic children between a panting technique and a single-breath technique for delivery of albuterol via pMDI/HC, but confirming this in a large, multicenter study would be of considerable interest.

Closa et al[57] studied 34 infants, age 1–24 months, in the ED for acute wheezing. Each patient received two treatments of terbutaline at 20-minute intervals via nebulizer (2 mg/dose) or via pMDI/HC (0.5 mg/dose). The clinical score 20 minutes after treatments revealed significant improvement, with no difference in rate of improvement between groups.

Schuh et al[58] compared treatment with a single dose of albuterol delivered via pMDI/HC or via nebulizer in either a weight-adjusted high dose or a standard low-dose regimen. Ninety children, age 5–17 years, presenting to the ED with mild asthma (FEV_1 50–79% of predicted) were randomly assigned to receive either 6–10 puffs or 2 puffs via pMDI/HC, or 0.15 mg/kg albuterol via nebulizer. All patients had improvement in clinical indices, with no significant differences between groups. The nebulizer group had a significantly greater change in heart rate ($p = 0.0001$).

In summary, pMDI/HC has been proven to be at least as effective as nebulizer in the treatment of children and infants presenting to the ED with acute asthma, with pMDI/HC having some advantages in reduction of adverse systemic effects and time of treatment, compared to nebulizer (see Table 5).

Published Reviews and Meta-Analyses

Several reviews of the literature and meta-analyses have been published in recent years, involving extensive examination of available evidence comparing the use of pMDI/HCs and nebulizers for treatment of acute airway obstruction in the ED.

Turner et al[12] published a meta-analysis comparing the effect of bronchodilator delivery by use of a metered-dose inhaler or wet nebulizer on objective measurements of acute airflow obstruction in adult patients. From 159 potentially relevant citations, 12 studies with a total of 507 patients had sufficient data to calculate an effect size (in standard deviation units) for improvement in airflow obstruction after bronchodilator delivery. All but two studies used pMDI/HCs. The overall treatment effect size was −0.02 (95% confidence interval [CI], −0.20 to 0.16), favoring the pMDI, but the magnitude of the effect size was not clinically or statistically significant. No significant effect was observed in the subgroup analyses that compared the diagnosis: asthma, −0.17 (CI, −0.41 to 0.07) compared with COPD, 0.23 (CI, −0.35 to 0.81); bronchodilator dose; or methodological quality. The results of a sensitivity analysis that included 5 of 6 excluded studies supported the findings from the primary analysis: 0.05 (CI, −0.11 to

Table 4. Randomized Controlled Studies Comparing Pressurized Metered-Dose Inhaler to Nebulizer for Bronchodilator Resuscitation in the Emergency Department—Adults

Study (year)	Population (*n*)	Devices	Dose	Frequency	Remarks
Salzman (1989)[38]	Asthma, adults, FEV_1 < 50% of predicted, (44)	MDI/HC (AC) Nebulizer	1.95 mg MET 15 mg MET	One treatment	No significant trend to improved FVC and FEV_1 with MDI/HC.
Colacone (1993)[39]	Asthma, adults, FEV_1 < 36% of predicted, (85)	MDI/HC (AC) Nebulizer	0.4 mg ALB 2.5 mg ALB	Every 30 min to maximum response	No significant difference between groups.
Idris (1993)[40]	Asthma, ages 10–45 y, ED, FEV_1 < 40% of predicted, (35)	MDI/HC (IE) Nebulizer	0.4 mg ALB 2.5 mg ALB	Every 30 min times 6	No significant difference between groups. Less time with MDI/HC.
Rodrigo (1993)[41]	Asthma, adults, ED, FEV_1 < 50% of predicted (97)	MDI/HC (V) Nebulizer	0.4 mg ALB 1.5 mg ALB	Every 10 min Every 15 min over 3 h	No significant difference between groups.
Rodrigo (1998)[42]	Asthma, adults, FEV_1 < 50% of predicted (22)	MDI/HC (V) Nebulizer	0.4 mg ALB 2.5 mg ALB	Every 10 min Every 15 min times 3 h	No significant difference in lung function improvement. Nebulizer group had greater serum albuterol levels, increased tremor, and anxiety.
Turner (1988)[44]	Asthma, COPD, adults, FEV_1 < 50% of predicted, (75)	MDI/HC (IE) Nebulizer	1.95 mg MET 15 mg MET	Every 30 min times 3	No significant difference between groups.
Levitt (1995)[45]	Asthma, COPD, adults, FEV_1 < 30% of predicted, (40)	MDI/HC (AC) Nebulizer	≤ 2.4 mg/h ALB 15 mg/h ALB	Dose/h for 3 h	No significant difference between groups.
Mandelberg (1997)[46]	Asthma/COPD, adults, FEV_1 < 32% of predicted, (50)	MDI/HC (V) Nebulizer	0.2 mg ALB 2.5 mg ALB	Every 15 min times 3	No significant difference between groups.

MDI/HC = pressurized metered-dose inhaler with holding chamber. AC = Aerochamber. MET = metaproterenol. ALB = albuterol. FVC = forced vital capacity. FEV_1 = forced expiratory volume in the first second. ED = emergency department. IE = InspirEase. V = Volumatic. COPD = chronic obstructive pulmonary disease.

0.20). They concluded that bronchodilator delivery via pMDI/HC or nebulizer is equivalent in the acute treatment of adults with airflow obstruction. The authors noted that pMDI/HCs were used in most studies (all studies in the ED) and pMDI/HCs were recommended for the treatment of acute airflow obstruction.

Looking at the COPD side, Kuhl, Agiri and Mauro[59] conducted a meta-analysis to critically evaluate the following issues regarding the use of beta agonists in the treatment of acute exacerbations of COPD: (1) optimal dose, and (2) use of nebulizers versus pMDI/HCs limited primarily to ED settings. Journal articles published between 1977 and 1993 were reviewed, with 9 studies evaluated that included beta agonists alone or in combination with other bronchodilators in the treatment of acute exacerbation of COPD. Dosing studies in patients with stable disease show a relationship between dose and the various pulmonary function tests. Dose also correlated with duration of action and incidence of adverse effects. Four studies compared nebulizers versus pMDI/HC, revealing significant improvement in pulmonary function tests for both treatments, with no significant difference between groups noted.

In 1999, a review by Cates[60] further supported the equivalence of nebulizers and pMDI/HCs for administration of beta agonists in the treatment of acute asthma. That review suggested that pediatric patients receiving beta agonists via pMDI/HC may have shorter ED stays, less hypoxia, and lower pulse rates compared to patients receiving the same beta agonist via wet nebulization. No outcomes were worse with the pMDI/HC in either adults or children (down to 2 years), even with adults with more severe asthma. Cates found no significant difference in hospital admission rate in either adults or children when the two delivery methods were compared. (Adults: odds ratio = 1.12; 95% CI: 0.45 to 2.76. Children: odds ratio = 0.71; 95% CI: 0.23 to 2.23.) Significant differences were observed in other outcomes, with pMDI/HC resulting in less ED time for children (weighted mean difference = −0.62 hours; 95% CI: −0.84 to −0.40 hours). pMDI/HC also resulted in lower pulse rates in children (weighted mean difference = −10.0% baseline; 95% CI: −14.13% to −5.87% baseline).

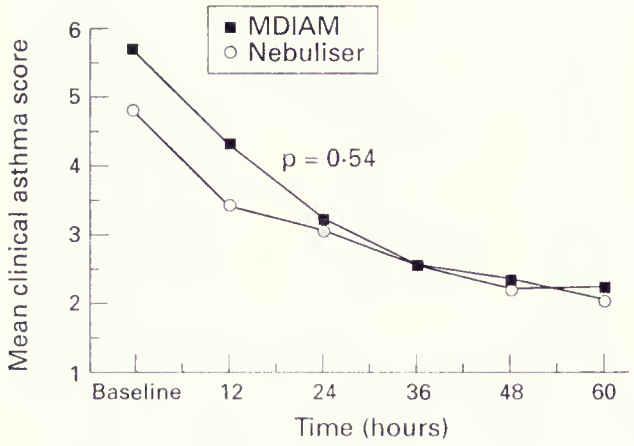

Fig. 9. Mean clinical asthma score over time for 60 pediatric patients, age 35 ± 1.9 months, receiving albuterol via pressurized metered-dose inhaler with holding chamber (MDIAM) (400–600 μg) with 2 puffs of ipratropium bromide (40 mg), or via nebulizer (0.15 mg/kg albuterol and 125 μg ipratropium bromide via face mask). All children received systemic steroids. Although the MDIAM group had higher initial scores, there was no difference in response between groups. (From Reference 50, with permission.)

The author noted that uncertainty over the dose required through any delivery method was overcome in several of the studies by using short treatment intervals (10–30 minutes) with either 2.5 mg of albuterol in saline or 4 puffs (400 μg) via holding chamber.[39–41,50] Dosage in the studies reviewed varied from 1:1 to 1:8 (with the lower dose being the pMDI). Colacone[39] plotted a log dose-response curve, finding an equivalent dose ratio of 1:6. Rodrigo, in more severe asthmatics, found an equivalent ratio of 1:2.[41]

Evidence suggests that the pMDIs should be actuated into the holding chamber in individual puffs that can be inhaled by tidal breathing or single breaths.[61] Some children were reported to cooperate better with either pMDI/HCs or nebulizers, so this may be a significant factor in choice of delivery method for the individual patient. None of the studies compared large-volume holding chambers with small-volume holding chambers.

Cates[60] concludes that pMDI/HCs produced outcomes that were at least equivalent to nebulizer delivery of beta agonists in acute asthma. Uncertainty over delivery of equipotent doses may be overcome by administering beta agonists at short intervals with titration of number of treatments to the patient's response. Adverse effects in children may be more pronounced with nebulizers.

In summary, these published reviews and meta-analyses support the view that pMDI/HCs are at least as effective as nebulizers for administration of beta agonist bronchodilators to infants, children, and adults presenting to the ED with moderate to severe airway obstruction. These data show that pMDI/HCs are equivalent to nebulizers in eliciting clinical response, and they offer a range of advantages in terms of reduced time for administration, reduced adverse effects, and better portability and convenience.

Role of Ultrasonic Nebulizers

Ultrasonic nebulizers (USNs) have been advocated by some for use in the acute care setting. Just as pneumatic nebulizers vary in performance based on design, operating flow, operating pressure, and fill volume, ultrasonic nebulizer models differ greatly in particle size and output.

The use of ultrasonic nebulizers has proliferated in treatment of ambulatory patients at home. Early work with these nebulizers and their high-density output of small particles was associated with precipitation of bronchospasm, raising the question of their place in the treatment of acute severe asthma. Sears[62] reported that the bronchodilator effect of fenoterol in 20 adults with moderately severe acute asthma was not enhanced by use of a USN, compared to a pneumatic jet nebulizer (JN), and that response to ipratropium bromide was significantly reduced with USN versus JN. Olivenstein et al[63] compared response to albuterol with pMDIs and USNs in 19 adult outpatients with stable obstructive pulmonary disease. Only the pMDI group had significant improvement, and absolute increase from baseline was greater with pMDIs (0.21 ± 0.05 L) than with USNs (0.07 ± 0.03 L; $p < 0.02$). The authors speculated that the inferior response was secondary to superimposed bronchospasm associated with the USN. In contrast, Ballard et al[64] reported on 17 adults with stable asthma in whom albuterol given via USN appeared to produce greater bronchodilation than the same dose of albuterol given by JN.

To better understand the role of the USN, Nakanishi et al[65] administered albuterol (0.15 mL/kg) to pediatric ED patients with severe asthma exacerbation using ultrasonic and pneumatic nebulizers. The USN was used with 46 children (initial FEV_1 36.1% of predicted) and the JN with 67 children (initial FEV_1 38% of predicted). The difference in the change in FEV_1 (USN +0.22 L vs JN +0.37 L) was significant ($p < 0.05$) and favored JN. There was no difference in the improvement in pulmonary function between JN and USN therapy in children with an initial $FEV_1/FVC > 75\%$ of predicted, but when FEV_1/FVC was $< 75\%$ of predicted the improvement in FEV_1 favored the JN (USN +0.2 vs JN +0.47; $p < 0.05$).

While USN may be comparable to JN in stable asthmatics, these reports do not support the use of USN in treatment of severe acute asthma in a comprehensive strategy of bronchodilator resuscitation.

Table 5. Randomized Controlled Studies Comparing Pressurized Metered-Dose Inhaler to Nebulizer for Bronchodilator Resuscitation in the Emergency Department—Children

Study (year)	Population (*n*)	Devices	Dose	Frequency	Remarks
Fuglsang (1986)[47]	Asthma, age 7–14 y, FEV_1 29% of predicted (21)	MDI/HC (N) Nebulizer	0.10 mg/kg TERB 0.10 mg/kg TERB	Once	MDI/HC > nebulizer increased FEV_1 ($p < 0.05$). More children expressed preference for MDI/HC because of shorter treatment time.
Kerem (1993)[48]	Asthma, age 6–14 y, FEV_1 40 ± 10% of predicted (33)	MDI/HC (V) Nebulizer	0.6–0.8 mg ALB 0.15 mg/kg ≤ 5 mg ALB	Once	No significant difference in improvement, but heart rate decreased in MDI/HC group.
Lin (1995)[49]	Asthma, children (111)	MDI/HC (AC) Nebulizer	0.75 mg TERB 2.5 mg TERB	Once	MDI/HC group had higher O_2 saturations and greater increase in PEF and FEV_1. Nebulizer group had increased risk of O_2 desaturation when nebulizer was operated with air compressor.
Parkin (1995)[50]	Asthma, age 1–5 y (60)	MDI/HC (AC) Nebulizer	0.4–0.6 mg ALB +40 μg IB 2.5–5 mg ALB +0.4 mg IB	Not specified	No significant difference between groups.
Chou (1995)[51]	Asthma, age ≥ 2 y, PEF < 56% of predicted, (152)	MDI/HC (AC) Nebulizer	0.2–0.4 mg ALB 0.15 mg/kg ≤ 5 mg ALB	Every 20 min	MDI/HC had shorter treatment time. Nebulizer group had more episodes of vomiting and higher heart rate.
Williams (1996)[52]	Asthma, age ≥ 6 y, PEF 46 ± 20% of predicted (96)	MDI/HC (AC) MDI/HC (ACE) Nebulizer	0.4 mg ALB 2.5 mg ALB	Every 20 min times 3	No significant difference between groups.
Batra (1997)[53]	Asthma, severe, age 1–12 y (60)	MDI/HC (C) Nebulizer	0.2 mg ALB 2.5 mg ALB	Once	No significant difference between groups.
Robertson (1998)[54]	Asthma, age 4–12 y (160)	MDI/HC (V) Nebulizer	0.6–1.2 mg ALB 2.5–5 mg ALB		Greater improvement in lung function with nebulizer.
Closa (1998)[57]	Asthma, age 1–24 mo (34)	MDI/HC (AC) Nebulizer	0.5 mg TERB 2 mg TERB	Every 20 min times 2	No significant difference between groups.
Schuh (1999)[58]	Asthma, age 5–17 y, FEV_1 50–79% of predicted	MDI/HC Nebulizer	0.2 mg ALB 0.6–1.0 mg ALB 0.15 ng/kg ALB	Once	No significant difference in clinical improvement between devices or doses. Nebulizer group had higher heart rate.

FEV_1 = forced expiratory volume in the first second. MDI/HC = pressurized metered-dose inhaler with holding chamber. N = Nebuhaler. TERB = terbutaline. V = Volumatic. ALB = albuterol. PEF = peak expiratory flow. AC = Aerochamber. IB = ipratropium bromide. ACE = Aerosol Cloud Enhancer. C = M/s Cipla (ns) 750 mL valved holding chamber.

Dry Powder Inhalers and Breath-Actuated Inhalers

Over the past decade, there has been increasing availability and use of dry powder formulations in the ambulatory setting, where dry powder inhalers (DPIs) have been shown to be comparable to both pMDIs and nebulizers. There is less information on the efficacy of DPIs in treating acute severe asthma. Concerns about the use of DPIs center on the inspiratory flow rate required to draw the drug powder out of the inhaler and the effect of flow reduction on patients experiencing severe acute airway obstruction. Because the energy from the patient's inspiratory flow draws the drug powder out of the inhaler, the magnitude and duration of the patient's inspiratory effort influence aerosol generation from a DPI.[66,67] Failure to perform inhalation at a fast inspiratory flow reduces the dose of the drug emitted from a DPI,[68] and increases the distribution of particle sizes within the aerosol.[69] Furthermore, the inspiratory flow influences the dose emitted from some DPIs to a greater extent than from others.[70] For example, the Diskus delivered approximately 90% of the labeled dose at inspiratory flow rates ranging from 30 to 90 L/min, whereas the dose delivered by a Turbuhaler DPI was significantly lower at 30 L/min than at 90 L/min, and variability between doses at various inspiratory flow rates was higher with the Turbuhaler.[71] Similar concerns are

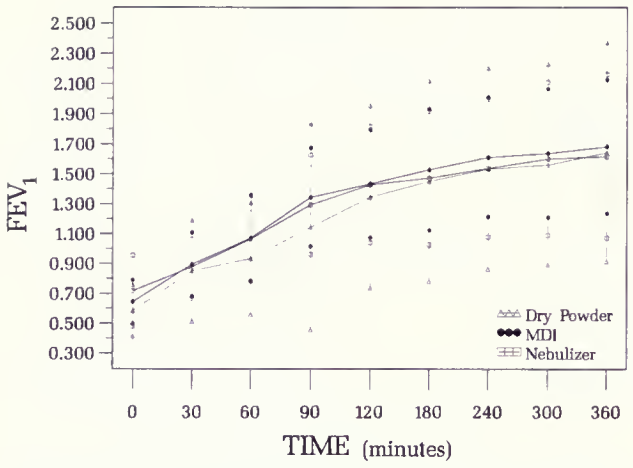

Fig. 10. Absolute changes in forced expiratory volume in the first second (FEV_1) (mean ± standard deviation) following cumulative doses of inhaled albuterol in 27 ED patients with $FEV_1 < 30\%$ of predicted. Subjects (9 in each group) were treated with albuterol via nebulizer (5 mg), pressurized metered-dose inhaler with holding chamber (MDI) (400 μg), or dry powder inhaler (DPI) (Rotahaler, 400 μg). All groups received treatments on arrival in the ED, every 30 minutes during the first two hours, and then hourly until the sixth hour. The total dose of inhaled albuterol administered during the 6-hour treatment was 45 mg of nebulized solution or 3,600 μg via MDI or DPI. All groups improved from baseline, with no difference between groups. (From Reference 73, with permission.)

associated with the use of breath-actuated pMDI devices that require ≥ 30 L/min inspiratory flow to trigger the device.

Roman et al[72] studied adult asthmatics admitted from the ED with acute asthma exacerbation and who received either 200 μg of albuterol via DPI or 2.5 mg of albuterol via nebulizer. They found greater absolute improvement with the nebulizer than with the DPI.

In a prospective, randomized, open design, Raimondi et al[73] studied the response to inhaled albuterol in 27 adult asthmatics with severe airway obstruction, presenting to the ED with $FEV_1 < 30\%$ of predicted. Subjects (9 in each group) were treated with either albuterol via nebulizer (5 mg), pMDI/HC (400 μg), or DPI (Rotahaler; 400 μg). All groups received treatment on arrival in the ED, every 30 minutes during the first two hours, and then hourly until the sixth hour. Clinical parameters and FEV_1 were recorded on ED admission and 15 minutes after each dose of albuterol. All patients received continuous oxygen and one dose of intravenous steroids (dexamethasone, 8 mg). The total dose of inhaled albuterol administered during the 6 hours of treatment was 45 mg of nebulized solution or 3,600 μg via pMDI/HC or DPI. FEV_1 improved significantly in all patients after the 6 hours of treatment (Fig 10). The 6-hour area under the FEV_1 curve improved similarly with the 3 delivery methods, despite differences in the total dose administered. Despite the relatively small number in each treatment group, these data support the view that the 3 delivery methods appear adequate to treat adult subjects with acute severe asthma.

Tonnesen et al[74] compared the bronchodilating effect of terbutaline (2.5 mg of terbutaline administered at 15-minute intervals) via DPI (Turbuhaler) or via pMDI/HC in 68 consecutive ED patients suffering acute severe bronchial obstruction. The mean baseline FEV_1 values were 0.81 ± 0.64 L (standard deviation) in the DPI group ($n = 33$), and 0.90 ± 0.90 L in the pMDI/HC group ($n = 29$). The mean increases in FEV_1 from baseline were 0.4 ± 0.40 L and 0.21 ± 0.25 L ten minutes after the last inhalation via DPI and pMDI/HC, respectively ($p = 0.0004$).

Nana et al[75] studied 86 adult asthmatics with severe obstruction ($FEV_1 < 37\%$ of predicted). Patients were randomized to receive albuterol via DPI (Turbuhaler) or pMDI/HC. The clinical response improved with both groups, with no significant differences between groups. A larger decrease in serum potassium levels occurred with the pMDI/HC group.

Sole et al[76] studied 47 ED pediatric patients, age 6–14 years, suffering acute mild or moderate asthma exacerbation (clinical score 3 or $FEV_1 < 50\%$ of predicted) treated with terbutaline sulphate via DPI or nebulizer. Both groups had significant improvement in clinical score (starting at 15 minutes) ($p < 0.05$) and in FEV_1, vital capacity, and forced expiratory flow (25–75%) (starting at 5 minutes) ($p < 0.05$). At the end of the first treatment, the number of patients with $FEV_1 < 80\%$ was similar in both groups.

In an open random study in parallel groups, Rufin et al[77] assessed 30 children, age 4–14 years, presenting with asthma exacerbation. After a baseline measure of pulmonary function, the children inhaled 500 μg of terbutaline via DPI (Turbuhaler) or pMDI/HC. There was significant improvement in both groups, measured at 15 minutes and 30 minutes after the treatment, with no difference between groups.

Ruggins et al[78] conducted a randomized, double-blind, two-period crossover study comparing the ability of 51 hospitalized asthmatic children with acute exacerbation to use a breath-actuated metered-dose inhaler, the Autohaler, and a DPI (Rotahaler). Peak inspiratory flow was sufficient in all children (30 L/min) to trigger the Autohaler, including the youngest, age 4 years (Fig. 11). No significant difference was found between the two inhalers as assessed by PEFR. However, the Autohaler inhalation device could be successfully actuated 99/100 times, compared with 74/100 for the Rotahaler. There was a consistent but clinically unimportant increase in pulse rate after use of the Rotahaler, compared with the Autohaler. All 11 patients under 6 years of age failed to empty the Rotahaler, but 5 of these patients received a significant benefit from using the Autohaler, compared with after the Rotahaler. A

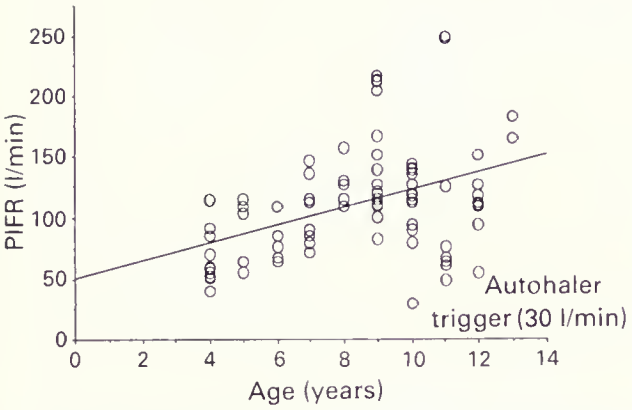

Fig. 11. Relationship between the peak inspiratory flow rate and age of wheezy children, age 4–13 years. The authors noted that these peak inspiratory flow rates were adequate to activate the breath-activated pressurized metered-dose inhaler (pMDI) (Autohaler) 99% of the time, versus 74% for the DPI (Rotahaler). (Not shown in figure.) (From Reference 78, with permission.)

significant drop in oxygen saturation was observed 15 minutes after use of either inhaler.

Different devices with the same medication can result in different levels of in vivo deposition. Lipworth and Clark[79] compared lung delivery of albuterol from two DPIs, Dishaler and Diskus, and the Easi-Breathe breath-activated pMDI. In a randomized, single-blind, crossover study, 10 healthy volunteers inhaled 1200 μg of albuterol over 6 minutes. Lung delivery was greater with the Diskhaler and pMDI than with the Diskus. Serum albuterol levels were determined at 5, 10, 15, and 20 minutes after inhalation. Peak concentration for the Diskhaler (4.34 ng/mL) and Easi-Breathe (3.98 ng/mL) were greater than the Diskus (3.22 ng/mL). Similarly, average concentrations were greater for the Diskhaler (3.95) and Easi-Breathe (3.52) than for the Diskus (2.62). Table 6 summarizes the differences in inhalation technique between pMDIs and DPIs, and Tables 7 and 8 summarize the results of studies comparing DPIs with pMDI/HCs and nebulizers.

In a parallel, randomized, placebo-controlled clinical trial of 24 patients, age 18–55 years, in the ED with acute asthma and an initial FEV_1 40–70% of predicted, Silverman et al[80] compared the efficacy of the Autohaler with inhaled beta agonist administered via wet nebulizer in treating acute asthma exacerbations. Patients were given either 6 puffs from the Autohaler (1,200 μg pirbuterol) plus saline solution via nebulizer, or 6 puffs placebo plus 2,500 μg albuterol sulfate solution via nebulizer. Treatments were repeated at 30 and 60 minutes, with clinical evaluation before each treatment, and at 120 minutes. Baseline FEV_1 was 53% of predicted for both groups, and at 120 minutes FEV_1 was 66% for the Autohaler group and 64% for the nebulizer group. Time for adminstration was 2.9 minutes with the Autohaler versus 9.1 minutes with the nebulizer. No patient was excluded due to inability to use the Autohaler device adequately.

Effect of Positive-Pressure Breathing

While the use of intermittent positive-pressure breathing (IPPB) treatments has been criticized for lack of evidence supporting its use, there has been an increased interest in the use of bi-level and noninvasive ventilation in the ED and intensive care unit. Many of the patients benefiting from these interventions may benefit from bronchodilator resuscitation, raising the question of how such medications should be administered. The relatively high flow rates used in many continuous positive airway pressure (CPAP) and bi-level systems are suspected of increasing aerosol impaction prior to inhalation. Similarly, the use of mask versus mouthpiece is thought to further reduce deposition of aerosol to the lungs, reducing clinical efficacy.

In 1977, Dolovich et al[81] found that aerosol administration with IPPB resulted in 30% less aerosol delivery to the lungs than use of the nebulizer alone. In 1983, the use of IPPB was found not to improve the effect of nebulized bronchodilator.[82] More recently, Loren et al[83] compared administration of isoproterenol hydrochloride via pMDI, pneumatic nebulizer, and IPPB to 23 children with severe bronchospasm (PEF < 25% of predicted) and found all 3 methods to be similar in reversing the bronchospasm. IPPB therapy did not offer any advantage over simple nebulization in patients with severe, reversible airway obstruction, but was no less effective.

Reporting in 1992 on a randomized, single-blind study, Lowenthal and Kattan[84] compared the use of mouthpieces and face masks with nebulizers for delivery of medication in 64 children, age 6 to 19 years, presenting to the hospital with acute asthma (Fig 12). There was no significant difference in improvement between the groups. Patients with nasal congestion, age < 10 years, or severe airway obstruction did equally well with each method. Patients in the face mask group had a higher incidence of tremor. The authors concluded that the mouthpiece is as effective as the face mask and produces less tremor.

CPAP has been shown to decrease pulmonary resistance and increase expiratory flow in induced bronchial asthma,[85] indicating that expiratory positive pressure dilates the airways, improves the distribution of ventilation, and might improve deposition of simultaneously-inhaled medication. This was confirmed by Wang et al,[86] who reported that in asthmatic adults, nasal CPAP (6 cm H_2O for 10 minutes) significantly reversed methacholine-induced bronchoconstriction, increasing FEV_1 by 15 ± 4% and peak inspiratory flow by 32 ± 11%. Nasal CPAP significantly increased the response to bronchodilators. The im-

Table 6. Differences in Inhalation Technique Between Metered-Dose Inhalers and Dry Powder Inhalers

	MDI/HC	DPI
Shaking the inhaler	+	–
Actuation with inspiration	Optional	Essential
Inspiration	Slow, deep improves deposition	Fast, prolonged required for deposition
Interval between doses	30–60 s	20–30 s
Exhalation into device	Small decrease in dose	Large decrease in dose

MDI/HC = metered-dose inhaler with holding chamber. DPI = dry powder inhaler.

Table 7. Dry Powder Inhalers in the Emergency Department—Adults

Study (year)	Subjects (*n*)	Devices	Medication	Results
Roman (1993)[72]	Moderate to severe asthma (30)	Nebulizer DPI (Rotahaler)	ALB	Nebulizer group had greater improvement than DPI group
Raimondi (1997)[73]	Severe asthma, adults, FEV_1 < 30% of predicted (27)	Nebulizer MDI/HC (Aerochamber) DPI (Rotahaler)	ALB	No difference between groups
Tonnesen (1994)[74]	Severe asthma (68)	MDI/HC (Nebuhaler) DPI (Turbuhaler)	TERB	No difference between groups
Nana (1998)[75]	Severe asthma, FEV_1 < 37% of predicted (86)	MDI/HC (Volumatic) DPI (Turbuhaler)	ALB	No difference between groups

DPI = dry powder inhaler. ALB = albuterol. FEV_1 = forced expiratory volume in the first second. MDI/HC = metered-dose inhaler with holding chamber. TERB = terbutaline.

Table 8. Dry Powder Inhalers in the Emergency Department—Children

Study (year)	Subjects (*n*)	Devices	Medication	Results
Sole (1995)[76]	Mild to moderate asthma, 6–14 y (47)	Nebulizer DPI	TERB	No difference between groups
Ruffin (1993)[77]	Moderate asthma, 4–14 y (30)	MDI/HC DPI	ALB	1–2 doses twice a day
Ruggins (1993)[78]	Asthma, 4–12 y (51)	Breath-actuated MDI DPI	ALB	All 11 patients < 6 y failed to empty Rotahaler

DPI = dry powder inhaler. TERB = terbutaline. MDI/HC = metered-dose inhaler with holding chamber. ALB = albuterol.

provement in airflow persisted for at least 5 minutes after nasal CPAP withdrawal and was highly correlated with the response to bronchodilators. There was no significant effect of nasal CPAP on airflow in COPD patients.

CPAP is often applied with high rates of gas flow delivered via nasal or face mask, conditions that would be expected to reduce aerosol availability to the respiratory tract. Parkes and Bersten[87] used a bench model simulating spontaneous respiration to compare the delivery of technetium-labeled aerosol generated from a jet nebulizer with and without CPAP at 10 cm H_2O at a flow of 50 L/min. CPAP significantly reduced total aerosol delivery to the face mask, from 6.85 ± 1.5% to 1.3 ± 0.4%. However, in a separate in vivo study, incremental doses of albuterol administered to 9 stable asthmatic subjects produced similar dose-response curves and identical magnitude of the total increase in FEV_1 for CPAP and control conditions. Despite a 5-fold reduction in aerosol delivered to the face, adequate aerosol was delivered to produced a bronchodilator response.

Frischknecht-Christensen, Norregaard, and Dahl[88] performed a randomized crossover study with 10 asthmatic adults and 2-week treatment periods to determine the effect of positive expiratory pressure at 10–20 cm H_2O, with and without 2 puffs (0.5 mg) of terbutaline via pMDI/HC, in treatments performed 3 times a day. All treatments increased PEF ($p < 0.0001$) (Fig 13). The mean increase in PEF was greater with positive expiratory pressure and terbutaline (32 L/min) than with terbutaline alone (25 L/min) or positive expiratory pressure alone (18 L/min). These

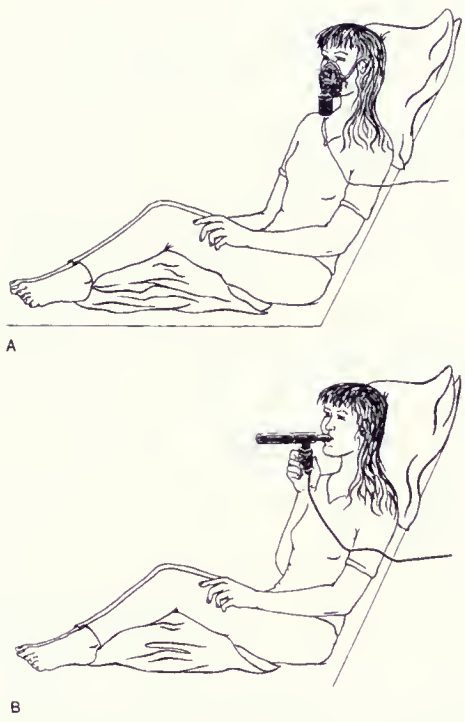

Fig. 12. Lowenthal and Kattan compared use of mouthpieces and face masks with nebulizers in a randomized, controlled study of 64 asthmatic children, age 6–19 years, with no difference in clinical endpoints.[84] (From Reference 93, with permission.)

data imply a potential benefit of aerosol delivery with positive expiratory pressure in stable asthmatics.

Pollack et al[89] randomly assigned adult patients with moderate asthma to receive two doses of aerosolized albuterol (2.5 mg in 3 mL normal saline solution) 20 minutes apart, delivered either via nebulizer (n = 40) or bi-level ventilation (n = 60) via nose mask[58] or face mask (inspiratory positive airway pressure 10 cm H_2O, expiratory positive airway pressure 5 cm H_2O). They found that bi-level patients had a significantly greater increase in percentage PEF after each treatment ($p = 0.0011$) and from baseline to completion ($p = 0.0013$). Increase in absolute PEF was greater in the bi-level group (from 211 ± 89 [standard deviation] to 357 ± 108 L/min for bi-level, and from 183 ± 60 to 280 ± 87 L/min for nebulizer; $p = 0.0001$). The authors concluded that, in this population, response to initial ED management of bronchospasm, as measured by PEF, was better with aerosols delivered via bi-level ventilation than via nebulizer.

While IPPB and CPAP have been shown to reduce aerosol delivery in vitro and in vivo compared to nebulizers alone, it appears that there is still sufficient delivery to elicit a bronchodilator response. Limited evidence indicates that CPAP, positive expiratory pressure, and bi-level ventilation may actually increase response to bronchodilator aerosols, but further studies are required to establish any beneficial effects of CPAP and bi-level ventilation with aerosol delivery during bronchodilator resuscitation of severe airway obstruction.

Device Selection

In the face of evidence that a variety of devices, properly applied, have comparable effect, selection should then be based on specific performance, convenience, drug availability, and costs, as shown in Table 9.

Myths or Facts

If clinical efficacy is similar between pMDI/HCs and nebulizers in the ED, when and why would we actually use the nebulizer? Device selection between pMDI/HCs and nebulizers is often premised on the ability of the patient to take a deep breath and to hold that breath for at least 4 seconds. This distinction has been emphasized in several consensus documents[3,90] that offer "expert opinion" that the inability to take a deep breath and hold it should be used as exclusion criteria for the use of a pMDI in favor of a nebulizer. While evidence supports that deep breaths and breath-holding improve deposition of any inhaled aerosol,[18] it has not been demonstrated that this is unique to the pMDI. A breathing pattern of shallow, rapid breaths without a breath-hold serves to reduce lung deposition of aerosol from any aerosol generator. This limitation is best countered with an increased dose of bronchodilator, titrating to effect.

The evidence clearly establishes that the administration of bronchodilator aerosols with pMDI/HCs is at least as effective as use of nebulizers, with some additional advantages in children. Of course, demonstrating that two aerosol delivery methods are not different does not prove that they have the same effect on every patient. Some patients just respond better to one device than to another. This preferential response, when it exists, can be empirically determined by improvement in lung function or subjectively by soliciting patient preference. We suggest that device selection is best determined by the clinician at the bedside, working with the patient.

Patient Education and Empowerment

Perhaps the paradigm of health care that we value could help guide the selection process. The longstanding paradigm of the patient as passive recipient has long been the standard of hospital-based care.[91] In this paradigm, once the patient enters the ED, the role of the health care team is to take care of the patient. In this case, the pMDI that the patient is prescribed for use at home is taken away in the ED and replaced with a nebulizer until the patient is discharged from the ED or hospital with one or more pMDIs

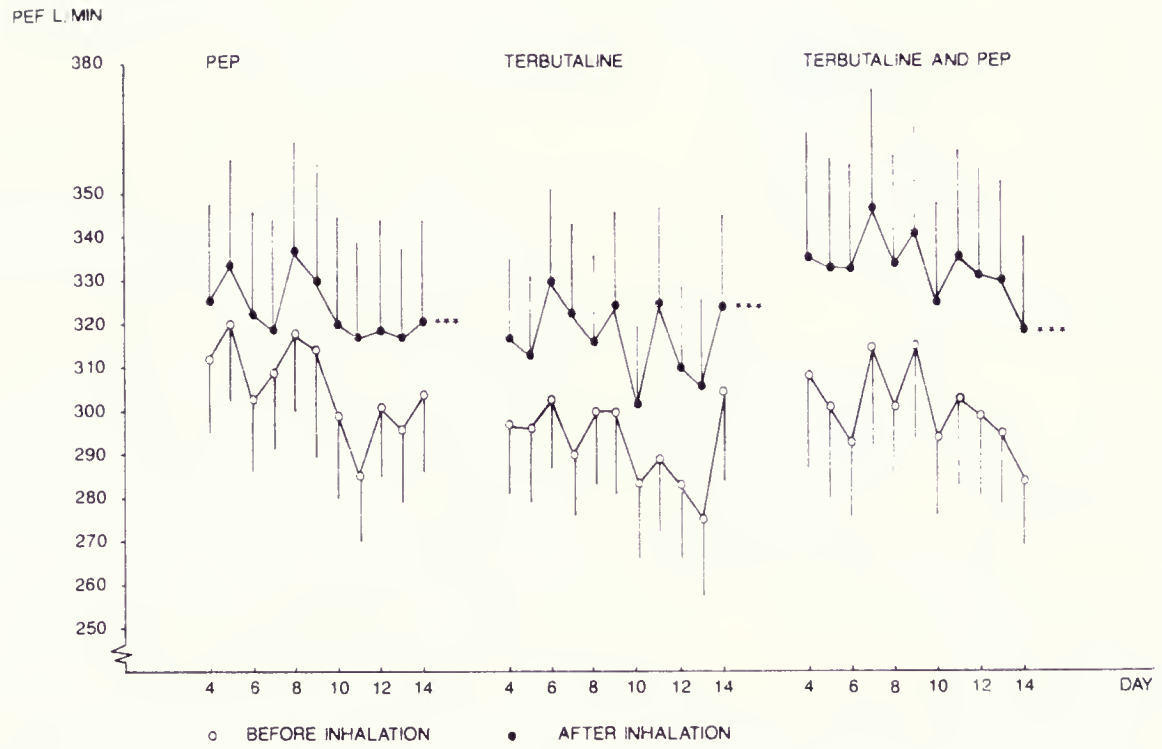

Fig. 13. The peak expiratory flow (PEF) before inhalation (lower curves) and after inhalation (upper curves) with: positive expiratory pressure (PEP) therapy (10–15 cm H_2O) and placebo (left); terbutaline (0.5 mg) via pressurized metered-dose inhaler with holding chamber (middle); or terbutaline (0.5 mg) with positive expiratory pressure (right). Improvement in PEF was greatest with terbutaline plus positive expiratory pressure ($p < 0.005$). (From Reference 88, with permission.)

reordered for home use. This approach creates the perception that the tools the physician prescribes for self-administration are less effective than the nebulizer used in the ED, and that when the patient has trouble breathing he or she needs to go to the ED to get the "good stuff" (the nebulizer) that will make the patient feel better. There is little opportunity in this scenario for the patient to learn how to get the desired therapeutic effects from that same medication (in the pMDI) when the patient is outside the hospital.

The emerging paradigm of health care embraces patients as active participants in the health care team. The patient is educated in many aspects of health and disease, with strategies for self-management that help avoid visiting the ED or hospital. In this paradigm, failure to get relief from bronchodilators is not an issue of device efficacy, but rather of how the device is used, with the possibility that factors such as hand-breath coordination may suffer with increasing dyspnea. Rather than replace the pMDI with a nebulizer, we would add a holding chamber to the pMDI, taking the opportunity to evaluate patient technique, reinforce proper technique, and demonstrate to the patient that the pMDI/HC can in most cases provide relief of symptoms. This approach encourages integration of devices with medication and action plan, reinforces proper technique, and is best implemented with continuity across the health care organization, from the ED, hospital, and clinic to home.

At our institution, educational consistency for the patient has been a priority, and we have attempted to base our ED bronchodilator resuscitation strategies on the tools and techniques that our patients are asked to use at home.

Staff Knowledge

Another important consideration in device selection is the comfort level and familiarity of staff with the devices and strategies used. Hanania et al[92] surveyed medical personnel to assess their knowledge of and ability to use 3 widely-used inhaler devices: pMDI, pMDI/HC (AeroChamber), and a DPI (Turbuhaler). Thirty respiratory therapists (RTs), 30 registered nurses (RNs), and 30 medical house staff physicians (MDs) were asked to demonstrate the use of each device using placebo inhalers and to answer 11 clinically relevant questions related to the use and maintenance of the tested devices. The RTs' percent mean knowledge score (67 ± 5%) was significantly higher than that of either the RNs (39 ± 7%) or the MDs (48 ± 7%) (for all $p < 0.0001$). Similarly, percent mean demonstration scores for each device were significantly higher for

Table 9. Comparison of Metered-Dose Inhalers With Holding Chambers, Dry Powder Inhalers, and Nebulizers as Aerosol Delivery Devices

Performance	MDI/HC	DPI	Nebulizer
Majority of aerosol particles < 5 μm	+	+	±
High pulmonary deposition	+	±	±
Low mouth deposition	+	±	−
Reliability of dose	+	±	±
Influenced by humidity	−	+	−
Physical and chemical stability	+	+	+
Breath-actuated	−	+	−
Risk of contamination	−	−	+
Convenience Factors			
Lightweight, compact	+	+	−
Multiple doses	+	+	−
Dose indicator	−	+	−
Dose counter	−	+	−
Inexpensive	+	+	−
Easy and quick operation	±	±	−
Suitable for all ages	+	−	+
Suitable for multiple clinical situations	+	±	+

RTs than for either RNs or MDs: for pMDI, 97 ± 3% versus 82 ± 13% and 69 ± 24%, respectively ($p < 0.0001$); for the Aerochamber, 98 ± 2% versus 78 ± 20% and 57 ± 31% ($p < 0.0001$); and for the Turbuhaler, 60 ± 30% versus 12 ± 23% and 21 ± 30% ($p < 0.0001$). Knowledge of and practical skills with the devices were roughly proportional to the length of time the device had been in clinical use, Turbuhaler demonstration scores being lower than either pMDI or Aerochamber scores ($p = 0.05$ and $p = 0.09$, respectively). More RTs (77%) had received formal instruction in school on the use of devices than either RNs (30%) or MDs (43%) ($p < 0.05$). The authors concluded that (1) many medical personnel responsible for monitoring and instructing patients in optimal inhaler use lack rudimentary skills with these devices, (2) nurses and physicians seldom receive formal training in the use of inhalers, and (3) newer inhaling devices designed to obviate problems of technique are at present less likely to be used well by medical personnel soon after their introduction. To better familiarize staff with these devices, professional continuing education, especially for the ED staff, would appear to be warranted.

Cost

Cost considerations may dictate which delivery system is used in different settings. For example, a nebulizer ($1.00) used in the hospital may be less expensive than a pMDI/HC ($12.00) in terms of acquisition cost, unless the patient is sent to the floor or home with the pMDI/HC after discharge from the ED. However, continued treatment with a nebulizer at home is much more expensive than a pMDI/HC in terms of medication and supply costs. Labor costs have been shown to be higher with the nebulizer than with the pMDI/HC, both in the ED and during hospitalization.[5,6] Table 10 costs out 3 common methods of bronchodilator resuscitation in the ED.[93] By far, labor is the greatest cost associated with any of the 3 methods, which means that convenience, effort, and time required for administration are paramount.

Summary

The pMDI/HC is equivalent to nebulizer therapy for treatment of infants, children, and adults with moderate to severe asthma. There may be some advantage in reduced treatment time and reduced adverse systemic effects for children with pMDI/HCs. The USN is less effective than the pMDI/HC or pnuematic nebulizer for treatment of severe asthma. The DPI has been shown to work in some ED settings, but dose administration is flow-dependent, which is a concern regarding reduced dose available to smaller children and severely obstructed patients. The administration of aerosol via pMDI/HC or nebulizer, with positive airway pressure appears to offer some additional benefit but requires further study to determine the most effective methods of delivery and the benefit, if any, in treatment of severe airway obstruction.

For treatment of patients with moderate airway obstruction (secondary to acute asthma and COPD) the selection of aerosol device appears to be less of an issue in effecting clinical response than for patients with severe airway obstruction. In treating the most severe asthmatic (adult, child, or infant), the pMDI/HC has been demonstrated to be as effective as the nebulizer (or other available devices) in relief of airway obstruction, and appears to offer some advantage in fewer adverse effects. If the pMDI/HC works in the ED, with the sickest of patients, it should be equally effective in other settings as well. The evidence is abundant and clear: the debate on pMDI/HC versus nebulizer appears to no longer be a relevant issue.

In Part 2 of this review (which will appear in a future issue of RESPIRATORY CARE) we will explore the evidence supporting the use of high-dose and low-dose, intermittent versus continuous treatment, as well as combining beta agonist with anticholinergic agents.

PRODUCT SOURCES

Pressurized Metered-Dose Inhalers:

Autohaler, 3M Pharmaceuticals, Northridge CA
Easi-Breathe, Norton Healthcare UK

Table 10. Comparative Costs of Bronchodilator Delivery During Acute Exacerbation for 3 Hours of Treatment in the Emergency Department

	Continuous Nebulizer*	MDI	SVN
Equipment	$10 (HEART nebulizer)	$6.00 (holding chamber)	$1 (nebulizer)
Medication	$9.50†	$6.00‡	$2.67§
Personnel			
Time per hour or number of treatments	20 + 10 + 10 min	45 + 15 + 15 min	15 min × 9
Cost	$13.33	$25.00	$45.00
Total Costs	$32.83	$37.00	$48.67

MDI = metered-dose inhaler. SVN = small-volume nebulizer.
Continuous nebulizer and MDI with holding chamber are comparable in total costs as well as efficacy. Increased equipment and medication costs with continuous nebulizer are offset by reduced time required by the care giver at the bedside. Labor costs for each of the first 3 h drive SVN administration costs to more than 150% of continuous nebulizer or MDI with holding chamber, with no greater clinical benefit.
*All patients on continuous nebulizer should be closely monitored during administration. Cost of EKG and pulse oximetry has not been added.
†Medication costs for continuous nebulizer include 20 mL albuterol solution mixed with 180 mL 0.9% NaCl.
‡Reflects costs of an MDI canister containing 200 doses of 90 μg of albuterol ($0.03/puff). The actual medication cost of 72 actuations over 3 h is $2.16.
§SVN costs calculated with three 15-minute treatments each hour, for a 3-h period.
(Table adapted from data in Reference 93.)

Nebulizers:

High-Output Extended Aerosol Respiratory Therapy (HEART) nebulizer, Westmed, Lakewood CO

Dry Powder Inhalers:

Diskhaler, Glaxo Wellcome, Research Triangle Park NC
Diskus, Glaxo Wellcome, Research Triangle Park NC
Rotahaler, Glaxo Wellcome Inc, Research Triangle Park NC
Turbuhaler, AstraZeneca, Wilmington DE

Holding Chambers:

AeroChamber, Monaghan Medical, Syracuse NY
ACE Aerosol Cloud Enhancer, DHD Healthcare Canastota NY
InspirEase, Schering-Plough, Madison NJ
M/s Cipla, Mumbai, India
Nebuhaler, AstraZeneca, Wilmington DE
Volumatic, Glaxo Wellcome, Research Triangle Park NC

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Diffuse Panbronchiolitis: Poor Recognition Outside Asia and Implications of Treatment with Erythromycin

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Introduction
Incidence and Prevalence
  Genetic Factor
  Environmental and Infectious Factors
  Possible Misdiagnosis
Clinical Features
Pathology
Radiographic Findings
Prognosis and Treatment

Summary [Respir Care 1999;44(11):1375–1382] *Key words: diffuse panbronchiolitis, chronic obstructive lung disease, erythromycin, human T-cell leukemia virus, human leukocyte antigen, bronchiolitis, cystic fibrosis, neutrophilia, bronchiectasis, Kartagener's syndrome.*

Introduction

Diffuse panbronchiolitis (DPB), a sinobronchial syndrome with representative features, is a disease of unknown etiology. It is characterized by chronic airflow limitation and airway inflammation of the bronchioles. The incidence of DPB is primarily confined to individuals of Asian ancestry, especially Japanese people. However, several white, Hispanic, and black DPB patients living outside Asia have been reported since 1990.[1–7] Although these cases appear to be very rare, some DPB cases outside of Japan might be misdiagnosed as other obstructive lung diseases,[8] since the characteristics of DPB are not well recognized in Western nations. DPB cases are frequently complicated with chronic perisinusitis.[9] A disproportionate number of DPB patients carry the human leukocyte antigen (HLA) haplotype, HLA Bw54.[10–12] The onset of DPB resembles bronchial asthma, chronic bronchitis, pulmonary emphysema, and bronchiolitis obliterans, because it is clinically manifested by common symptoms such as dyspnea, cough, sputum, and wheeze. In the advanced stage, the large amount of purulent sputum and dilation of bronchioles are similar to bronchiectasis and cystic fibrosis. But DPB belongs to a distinctly different category and is histologically[9] and radiographically[13] distinguishable from other chronic obstructive lung diseases (COLDs). Correct diagnosis of DPB, particularly in the early stage, is quite important since it often progresses rapidly, followed by chronic infection with *Pseudomonas aeruginosa*, and this has specific implications for the therapy, low-dose erythromycin.[14]

Incidence and Prevalence

DPB was first described in 1969 by Yamanaka,[15] and a nationwide survey in Japan[9] identified 1,238 cases of probable DPB, 82 of which were confirmed histologically. Until recently, the majority of DPB cases appeared in Japan,[9] Korea,[16] and China,[17] and in a few cases in emigrants from those countries, reported in the United States[18] and Europe.[19] The first reported case in a non-Asian individual was in 1990, in an Italian patient.[1] Since 1990, 15 non-Asian cases, including 10 white, 2 Hispanic, and 3 black patients, in Europe[1,5] and North America[2–4,6,7] have been

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reported in the literature. Recurrence of DPB after lung transplantation suggests a systemic etiology,[6] but the geographic distribution may suggest a genetic association unique to Asia, or the contribution of environmental or infectious factors, bearing in mind that DPB may be underdiagnosed or misdiagnosed outside of Asia.[8]

Genetic Factor

In addition to racial susceptibility, some familial cases of DPB have been reported in Japan, further supporting a genetic etiology. In this regard, DPB was confirmed to have a close association with HLA haplotype.[10–12] HLA Bw54 was identified in 63% of DPB patients, versus 11% of Japanese individuals without DPB.[10] Moreover, this HLA haplotype is found in Japanese, Chinese, and Korean individuals, but not in other races.[10] Also, the frequency of HLA Bw54 is higher in Japanese patients with rheumatoid arthritis,[20,21] so immunological abnormality may be important in the progression of DPB. Bronchopulmonary complications are common in rheumatoid arthritis patients, and there are clinical similarities between DPB and rheumatoid arthritis-associated bronchiolar disease,[21] but the pathology findings of DPB are distinguishable from those of rheumatoid arthritis.[22] Although a genetic factor has been suggested to contribute to DPB, a gene has not been identified that might be responsible for DPB, whereas cystic fibrosis is well known to be related to the mutation of cystic fibrosis transmembrane conductance regulator (CFTR) protein.

Environmental and Infectious Factors

Unlike chronic obstructive pulmonary disease (COPD), there is no preponderance of DPB in smokers.[9] One patient among the 15 non-Asian cases had an extensive travel history to Japan,[5] suggesting that environmental factors may play a role in the pathogenesis of DPB. In Japan, a possible relationship between DPB and human T-cell leukemia virus-1 (HTLV-1) has been proposed. HTLV-1 is an oncogenic retrovirus that causes adult T-cell leukemia and is also known to cause inflammatory disorders such as HTLV-1-associated myelopathy. HTLV-1 carriers are more common along the western edge of the Pacific Ocean, especially on Kyushu Island in Japan. It has been reported that adult T-cell leukemia patients[23] and HTLV-1 carriers[24] are occasionally complicated with DPB, and that anti-HTLV-1 antibody in serum (35%)[25] and HTLV-1 proviral DNA in lung tissue (27%)[26] are significantly higher in DPB patients. Thus, HTLV-1 might be the cause of some cases of DPB but does not explain all cases. In some cases, the bronchopulmonary manifestations of adult T-cell leukemia are very similar to DPB but are distinguishable by pathology findings.[27]

Possible Misdiagnosis

Although numerous Asian immigrants live in North America and in Europe, only a few of them are affected by DPB,[18,19] suggesting that DPB is at least not solely due to genetic factors. However, Iwata et al[4] reviewed 81 cases of chronic cellular bronchiolitis in the United States and identified 7 cases with clinical and pathology features suggesting DPB. There were 3 Asian, 3 white, and 1 black individuals. Among them, only one case was diagnosed and treated as DPB. This study indicates that DPB is not limited to people of Asian ancestry and can go unrecognized.[8] Most of the non-Asian cases in the literature have been reported during the past 5 years.[4–7] The number of DPB cases identified will probably increase as the characteristics of the disease become more widely known.

Clinical Features

DPB is more prevalent in males; the male-to-female ratio is more than 2 to 1.[9] The age range of onset is 20–80 years.[9] The disease is rare in childhood, and most patients are over 40 years old when they present. Cystic fibrosis, on the other hand, is found in children.

Table 1 shows the diagnostic features of DPB. The clinical symptoms are chronic cough, exertional dyspnea, and sputum production. These are common symptoms in chronic lung disease, but in DPB the amount of sputum is relatively large, and often exceeds 200 mL per day.[9] The most characteristic feature and useful symptom for diagnosis of DPB is that almost all cases are complicated with or include a history of paranasal sinusitis,[9] though this can also be a characteristic of certain other bronchiectatic states, including cystic fibrosis and Kartagener's syndrome.

In DPB, pulmonary function tests show severe obstructive change, with increased air trapping, indicated by increased residual volume and reduced vital capacity, similar to advanced COPD. The diffusion capacity is relatively preserved, suggesting that the structural damage is limited to the bronchi and bronchioles. In DPB, bronchial hyperresponsiveness to methacholine and the effect of β-stimulants are less clear than in COPD,[28] suggesting irreversible structural change in the bronchioles. Wheezing and/or rhonchi are often audible. In the early stage, sputum is clear, but soon becomes yellow from repeated infection with *Haemophilus influenzae* or, sometimes, *Klebsiella pneumoniae*, *Streptococcus pneumoniae*, or *Staphylococcus aureus*.[9] In the advanced stage, these are replaced by chronic infection with *P. aeruginosa*.[9] Such repeated infection causes elevated serum immunoglobulin A and secretory immunoglobulin A,[29,30] as well as neutrophilia in bronchial alveolar lavage fluid (BALF).

In DPB patients, approximately 50% of cells recovered by bronchoalveolar lavage are neutrophils, whereas in

Table 1. Diagnostic Features of Diffuse Panbronchiolitis

Symptoms
• Chronic cough
• Purulent sputum
• Exertional dyspnea
• Weight loss
• History or coexistence of chronic parasinusitis
Physical signs
• Coarse crackles, rhonchi, or wheezes
Pulmonary function test
• FEV_1 < 70% of predicted value
• VC < 80% of predicted value
• RV > 150% of predicted value
• Diffusion capacity preserved or lowered
• P_{aO_2} < 80 mm Hg
Laboratory
• Cold-agglutinin titer elevated > 64-fold
• Serum IgA level elevated
Radiography and computed tomography
• Chest radiograph shows diffusely disseminated fine nodular shadows, mainly in the lower lung, and hyperinflation
• High-resolution computed tomography shows centrilobular nodules, with thickened and ectatic bronchioles
Histology
• Foam cell accumulation in the walls of respiratory bronchioles, with transmural infiltration of lymphocyte
• Proximal bronchioles often show bronchiectasis

FEV_1 = forced expiratory volume in the first second. VC = vital capacity. RV = residual volume. P_{aO_2} = arterial oxygen tension.

chronic bronchitis, neutrophils constitute 10–20% of BALF cells.[31] Interleukin 8 (IL-8), a neutrophil chemotactic factor, is also increased in BALF from DPB patients, and this increase is significantly correlated with the BALF neutrophilia.[32] Increased lymphocytes in BALF and a decreased CD4/CD8 ratio (the ratio of the number of helper-inducer T lymphocytes to cytotoxic-suppressor T lymphocytes) are also observed in DPB, but these differences are not significant.[33,34] Table 2 summarizes the characteristics of DPB and other COLDs.

Pathology

Histologic confirmation of the diagnosis is of primary importance, since DPB was first defined on the basis of pathology features,[15] and the clinical diagnostic criteria were described later from study of those cases.[9] The most characteristic pathology feature of DPB is chronic inflammation with infiltration of lymphocytes and an accumulation of foam cells (lipid-enriched cells derived from macrophages) in the wall of the respiratory bronchioles (Fig. 1). The respiratory bronchioles are just distal to the terminal bronchioles and are the transition zone between the airways and the pulmonary parenchyma.[9] The macroscopic features are fine yellow nodules on the surface of sliced lung, representing the findings described above. Other chronic respiratory diseases (eg, constrictive bronchiolitis, follicular bronchiolitis, and bronchiectasis) show inflammatory changes, but in those diseases more proximal membranous bronchioles and bronchi are primarily affected.[4] The prefix "pan" in "panbronchiolitis" indicates the fact that in DPB the inflammatory reaction spreads to all layers of the respiratory bronchioles and surrounding tissues.[9]

Bronchiolitis obliterans with organizing pneumonia also affects respiratory bronchioles but is characterized by proliferating and organizing changes. Foam cells are frequently seen in obstructive pneumonia, regardless of the cause, but they are usually much less abundant and are found in air spaces, whereas in DPB foam cells are found within the peribronchiolar interstitium.[4] In advanced-stage DPB, secondary ectasia of the proximal bronchioles is observed, which may result from the obstruction of respiratory bronchioles, but the precise mechanism is not yet fully understood. This ectasia is quite similar to that of cystic fibrosis and bronchiectasis, but those diseases are distinguishable by the location of the mainly affected bronchioles and by the number of foam cells. Open lung or transthoracoscopic biopsy is recommended for definitive diagnosis; specimens obtained by transbronchial lung biopsy are not adequate for distinguishing these diseases histologically, because the specimens are not large enough to include secondary lobules.

Radiographic Findings

Although a chest radiograph of early-stage DPB may show only lung hyperinflation, the most typical finding is diffusely disseminated small nodular shadows, up to 2 mm in diameter, with well-defined margins.[9] The dissemination is prominent regionally in bilateral lower lung fields (Fig. 2). These nodular shadows are uncommon in COLDs (including COPD and cystic fibrosis) but are often observed in various interstitial lung diseases, such as sarcoidosis and miliary tuberculosis. DPB is one of the representative diseases that extends application of computed tomography (CT) and high-resolution CT to the diagnosis of diffuse lung disease, since CT findings are specific and essential for the diagnosis of DPB. A CT scan of DPB shows the distribution of nodular shadows in a centrilobular area, and these are often connected to small and branching linear structures more than 1 mm apart,[13] like a tree in bud.[35] The nodular and linear densities correspond to the thickening of respiratory bronchioles and secondary ectasia of proximal bronchioles, respectively.[36] Thus, these nodules, separated from the pulmonary vein or pleura at a distance of about 2–3 mm, reflect that respiratory bronchioles are located in the central portion of the secondary lobule (Fig. 3A). As the disease progresses, the number of

Table 2. Characteristics of Diffuse Panbronchiolitis and Other Chronic Lung Diseases

	Age (y)	Etiology	Specific symptoms	Radiographic findings
Diffuse panbronchiolitis	> 20, but almost all patients over 40	• HLA Bw54? • HTLV-1?	• Parasinusitis (> 90%) • Copious sputum	• Hyperinflation • Small nodular opacities • Bronchiectasis
Cystic fibrosis	< 20 (childhood)	• Mutation in CFTR	• Copious sputum • Pancreatic insufficiency (85%)	• Cystic change • Nodular opacities
Chronic obstructive pulmonary disease	> 40	• Smoking • Defect of α_1-antitrypsin	• Progresses slowly	• Hyperinflation • Bronchial wall thickening
Bronchiolitis obliterans	All ages	• Rheumatoid arthritis • Viral infection • Hypersensitive • Lung transplantation	• Various	• Small nodular opacities
Bronchiectasis	All ages	• Idiopathic congenital (Kartagener's syndrome)	• Parasinusitis (50%) • Copious sputum (wet) • Hemoptysis (dry)	• Bronchiectasic change (tramline or ring-shaped opacities)
Sarcoidosis	> 20	• Racial and environmental factors?	• Uveitis	• Bilateral hilar lymphadenopathy • Nodular shadow (cotton-like appearance)

HLA Bw54 = human leukocyte antigen haplotype Bw54; HTLV-1 = human T cell leukemia virus; CFTR = cystic fibrosis transmembrane conductance regulator.

nodules decreases and ectatic changes in the proximal bronchioles become prominent, such as ring-shaped and small ductal opacities, suggesting that the inflammatory region extends to the bronchi and more proximal bronchioles.[13] These findings are also recognizable on a chest radiograph as ring-shaped or tramline-shaped shadows connected to proximal bronchovascular bundles. Because of impaired sputum drainage, the dilated bronchioles are often identified as mucus plugs, which are represented by tubular structures or rounded opacities.[37] Because these findings cannot be differentiated from blood vessels by chest radiograph, CT scan is useful to detect mucus plugs. In the terminal stage, the dilated peripheral airways may change to large cystic opacities accompanied by dilated proximal bronchi (Fig. 3B).[13] These features are quite similar to those of cystic fibrosis, but the ectasia of cystic fibrosis appears in the more proximal bronchioles, and the incidence of hyperinflation in DPB is relatively high. CT scan shows lung attenuation in the outer zone rather than in the inner zone, because hyperinflation can result from peripheral air trapping caused by bronchiolar obstruction in the subpleural zones.[36]

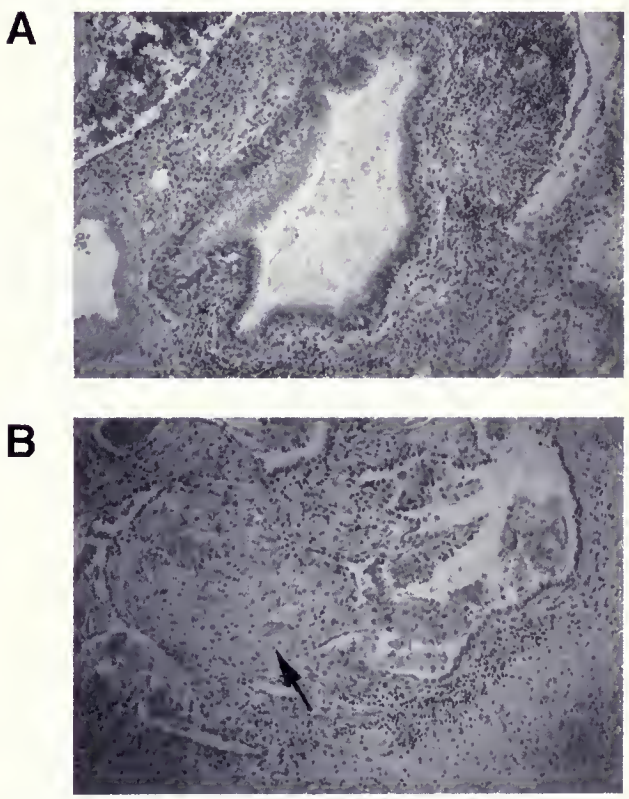

Fig. 1. Histologic view of diffuse panbronchiolitis. The respiratory bronchioles are thickened by infiltration of lymphocyte (A) and accumulation of foam cells (B).

Prognosis and Treatment

Before 1980, the prognosis for DPB patients was very poor, and the 5-year and 10-year survival rates were approximately 50% and 30%, respectively.[14] An important determinant of the prognosis is whether the patient is infected with *P. aeruginosa.* In the 1980s, 10-year survival

Fig. 2. Chest radiograph of diffuse panbronchiolitis shows hyperinflation and small nodular shadows spreading throughout both lower lungs.

rate was 12% in cases with *P. aeruginosa* infection and 73% in cases without *P. aeruginosa* infection.[38] In 1987, Kudoh et al[39] reported that long-term, low-dose administration of erythromycin improved survival rate and clinical symptoms in DPB patients. The 5-year survival rate of patients receiving low-dose erythromycin (400–600 mg per day) was more than 90%. In contrast, the patients who did not receive erythromycin had the severe survival rate of approximately 50%.

Several possible mechanisms for the efficacy of low-dose erythromycin therapy on DPB have been proposed. With the low dose level prescribed for DPB, the maximal concentration of erythromycin in the serum and sputum is below the minimum inhibitory concentration of *P. aeruginosa* and *H. influenzae*.[40] This suggests that the efficacy of erythromycin in DPB patients is related to something other than the antibacterial action. Erythromycin at low concentration showed no effect on the proliferation of the bacteria,[41] but showed some favorable effect on the actions of the bacteria, such as inhibition of elastase production[41] and interference with biofilm formation.[42] The biofilm is composed of polysaccharide matrix produced by the bacteria, and surrounds the bacterial colony, increasing resistance to the host defense systems and to antibiotics, because the bacteria incorporate with fibrin and thrombocytes, resulting in intractable airway infection.[42] Erythromycin inhibits the bacterial polysaccharide production,[42] even at concentrations less than the minimum inhibitory concentration.

The efficacy of erythromycin on DPB has also been suggested to be from its anti-inflammatory action.[43,44] Repeated infection causes infiltration of neutrophils and enhances the production of oxygen radicals and neutrophil elastase,[45] which may cause injury to airway epithelial cells, resulting in inhibition of cilial movement, impairment of mucociliary transport, and increased airway mucus discharge.[46] In addition, neutrophil elastase disrupts the constructive matrix, including collagen fibers, and degenerates immunoglobulin and complement components. These events impair host defense mechanisms and facilitate the formation of bacterial biofilm. In this context, the suppression of neutrophil function is particularly important. In DPB patients, the percentage and number of neutrophils in BALF are increased, but long-term, low-dose erythromycin therapy reduces the recovery of neutrophils in BALF.[47–49] Note that the reduction of airway neutrophilia is seen in patients treated with erythromycin, but not in those treated with ampicillin.[48] These in vivo findings might be explained by erythromycin's in vitro inhibition of IL-8 and leukotriene B4 production,[50,51] eliciting chemotaxis of neutrophils.[48,49,52] Long-term, low-dose erythromycin therapy improves clinical symptoms, lung function, and radiographic findings.[47–50] Small nodular shadows, mucus plugging, and periairway thickening apparent on radiographs improve with erythromycin therapy, but radiographic findings of ectasia show no response.[37,53]

Nagai et al[40] administered erythromycin to 19 DPB patients for 2 months and determined the efficacy of erythromycin on the improvement of lung function. They found significant increases in vital capacity (from 64% to 79% of the expected value), in forced expiratory volume in the first second (from 1,111 mL to 1,662 mL), and in arterial oxygen tension (from 66 mm Hg to 80 mm Hg). Several studies have confirmed the efficacy of long-term, low-dose erythromycin therapy on DPB.[14,47–49,50] Recently, newly manufactured macrolides such as roxythromycin and clarithromycin have also been reported to have favorable effects on DPB.[54,55] Oxitropium bromide, an anticholinergic bronchodilator, has been reported to reduce the production of sputum and to improve lung function of DPB patients.[56] Only one DPB patient has undergone bilateral lung transplantation, but DPB recurred in the lung allograft, with typical radiographic and histologic features 10 weeks later, indicating that lung transplantation is ineffective for DPB.[6]

Summary

DPB, a COLD, had been believed to be limited to individuals of Asian ancestry and closely associated with HLA Bw54, but this apparent genetic factor has been called into question because of an increasing number of non-Asian cases in North America and Europe. Three impor-

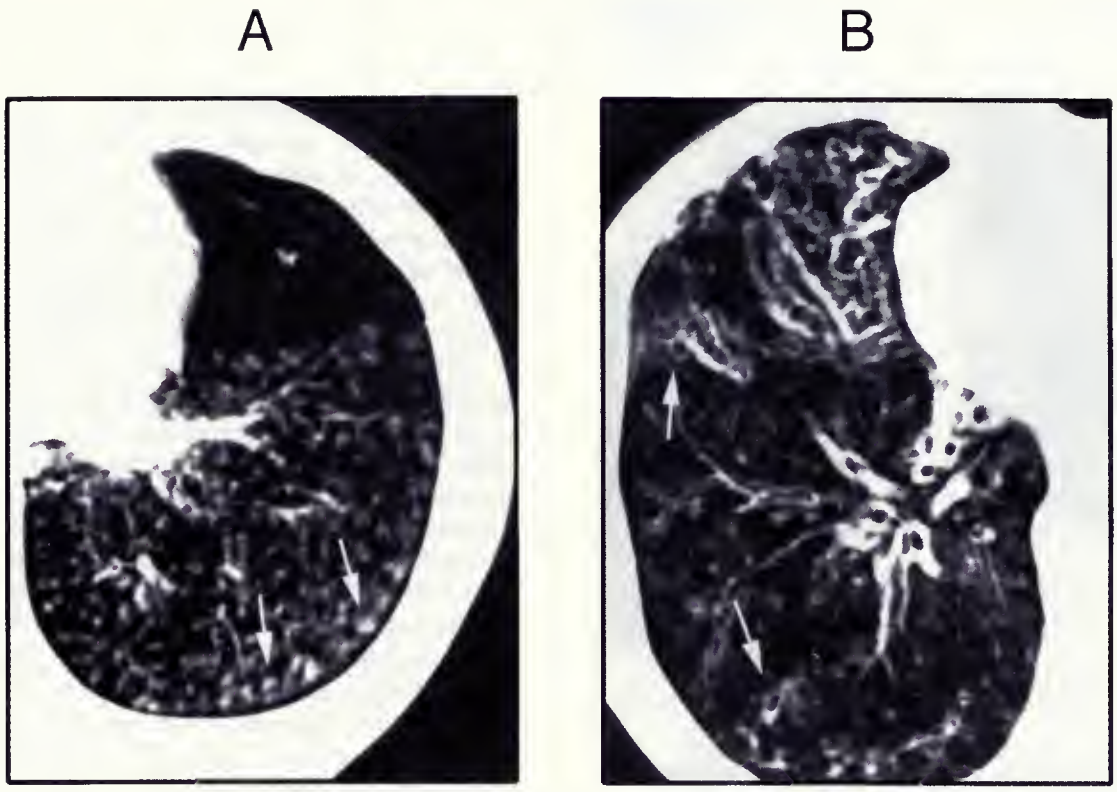

Fig. 3. A: Computed tomography scan of early-stage diffuse panbronchiolitis shows centrilobular nodular shadows (arrows) separated from the pleura at a distance of about 2–3 mm. B: Computed tomography scan of advanced-stage diffuse panbronchiolitis shows ring-shaped opacities (arrows) and dilated proximal bronchioles.

tant features characterize DPB: (1) almost all cases are complicated with perisinusitis; (2) histology findings show transmural inflammation in respiratory bronchioles and accumulation of a large number of foam cells; and (3) CT scan findings such as diffuse small nodular shadows with ectasia of proximal bronchioles and hyperinflation, predominantly in the outer zone, are unique. Although some DPB patients show rapid progression as repeating infection with *P. aeruginosa*, administration of low-dose erythromycin improves survival and prognosis.

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Withdrawing Mechanical Ventilation: Conflicts and Consensus

Mark R Tonelli MD

Introduction

Less than 25 years ago, attorneys for the physicians caring for Karen Ann Quinlan, a young woman in a persistent vegetative state, argued that withdrawing mechanical ventilation from a patient dependent on such an intervention violated the integrity of the medical profession.[1] By the early 1990s, however, the majority of deaths in many intensive care units were preceded by decisions to withhold or withdraw life-sustaining therapies.[2,3] The most common intervention withdrawn from such patients is mechanical ventilation.[4] Such a fundamental change in medical practice required fundamental changes in the understanding of the goals and ethical foundations of clinical medicine. Though these shifts in theory and practice have come rather rapidly, they did not develop in the absence of significant and often contentious debate. Nor has consensus been reached regarding all aspects of end-of-life care; serious philosophical disagreements persist and conflicts between patients, their families, and medical care providers regarding the provision of such care continue to arise. Understanding both the basis for consensus and the grounds for persistent disagreement are important for optimizing care at the end of life. This essay will examine these areas, with a particular focus on the withdrawal of mechanical ventilation.

Developing Consensus

The problem of patients requiring long-term mechanical ventilation, often without any real hope of meaningful recovery, actually predates the development of the discipline that has come to be called "bioethics." In his examination of the history of bioethics, Albert Jonsen notes that the earliest recognition of problems that would later be grouped under the heading "withdrawal of life-supporting therapy" came with the polio epidemics in America and Europe during the mid 20th century.[5] The use of the iron lung meant that some patients with profound paralysis and no significant chance of recovery might be kept alive indefinitely. Discussions regarding when, if ever, such support could be withdrawn were initially muted.

By the 1950s, positive pressure ventilation, developed for the operating room, began to be utilized for patients with neurologic catastrophes and cardiac decompensation—patients who previously would have died of respiratory failure. The list of indications for mechanical ventilation grew, but no one was quite sure when assisted ventilation could be discontinued in patients who had not sufficiently recovered. In 1957 an international group of anesthesiologists submitted questions regarding the appropriateness of discontinuing mechanical ventilation to one of the world's recognized moral authorities, Pope Pius XII.[5] Not coincidentally, these questions were posed by a European anesthesiologist, Dr Bruno Haid, whose own hospital had begun to provide prolonged positive pressure ventilation to nonsurgical patients, in essence creating an early prototype of the intensive care unit.

Involving the Pope in the discussion of what constituted appropriate medical care stemmed from a recognition that the problems confronting the new technological medicine were not purely clinical or scientific, but philosophical and ethical in nature. The notion of quality of life began to emerge as an important consideration, and the concept of death itself became ambiguous. Theology and theologians, accustomed to dealing with these larger issues, were recruited to aid medicine in addressing these issues. But in pluralistic societies, it also became clear that consensus on these issues would have to be grounded not solely in religion but also would have to be defensible from a more secular point of view. Philosophers were enjoined to enter into the debates, introducing into the discussion principles of ethical theory, including respect for individual autonomy. Whether invited by medicine or not, eventually legal scholars and the courts also became enmeshed in the discussions, and many seminal cases in the emerging bioethics were gleaned from the dockets of appellate courts.

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Though glossing over decades of sometimes contentious debates, several areas of widespread consensus have emerged from this intersection between medicine, philosophy and the law. First, there is widespread agreement that a competent individual has the right to refuse any medical treatment, even if it is life-saving or life-sustaining. This consensus is generally grounded in the Western tradition of respect for individual autonomy and in the strong American tendency toward the preservation of individual liberty. This means that a competent patient may refuse mechanical ventilation, even if such a refusal means that death will occur sooner than it might have if assisted ventilation were instituted. The decision should be, as best one can tell, made autonomously. That is, the fully-informed patient should voluntarily make the choice, free from coercion or inducement.

Consensus has also developed that noncompetent patients also have a right to refuse life-sustaining treatments, though how such a right ought to be exercised remains problematic. This will be discussed in more detail below.

Other areas of consensus have been reached regarding the lack of ethical relevance of certain distinctions drawn early in the debates surrounding withdrawal of life-sustaining therapies. For instance, Pope Pius XXII, in his 1957 address, distinguished between "ordinary" and "extraordinary" means of prolonging life.[5] Mechanical ventilation clearly fell in the "extraordinary" category and could be withdrawn in certain circumstances, while other interventions such as feeding and hydration were considered "ordinary" and, therefore, were not to be withheld or withdrawn. This distinction, however, was recognized as arbitrary and not ethically relevant.

Likewise, attempts to argue that there is a relevant ethical difference between withholding supportive therapy and withdrawing such support have also been largely discredited. That is to say, acts of withholding life-sustaining support do not differ from acts of withdrawing support in any ethically meaningful way. Either action should represent a respect for patient autonomy and be an exercise in beneficence, and both will result in identical consequences.

It is important to note that the lack of ethical distinction between ordinary and extraordinary means and between withholding and withdrawing support does not imply that there is no sociological or psychological distinction. Many patients and families will view the provision of hydration very differently than they view mechanical ventilation. Medical providers may feel differently about an agreement not to intubate a patient compared to withdrawing a ventilator from an individual already dependent on it for life. However, all life-sustaining interventions can be considered equivalent from an ethical standpoint, and the acts of withdrawing or withholding support under particular circumstances are ethically indistinguishable.

Widespread agreement also exists that withdrawing or withholding a life-sustaining intervention at the request of the patient does not constitute a homicide. The argument has generally been that allowing "nature to take its course" without unwanted medical intervention is not the same as actively killing an individual. This distinction has been clearly supported in United States case law. An ethical distinction between withdrawing support and active euthanasia or "mercy-killing" remains firmly entrenched in medicine and the law, however, despite some arguing that this distinction is not ethically relevant.

Withdrawal of life-sustaining therapy should not be viewed as withdrawal of care. Rather, the goals of medical care shift from the preservation of life and the restoration of health to the provision of comfort and a peaceful death. Sedation and analgesia, then, remain appropriate therapies in virtually all cases in which support is being withdrawn. Even recognizing that the administration of narcotics and sedatives may hasten death, primarily through respiratory depression, an ethical consensus has developed that such practice is not only defensible, but preferable, as long as the physician intends only to alleviate suffering, not directly cause death. This approach has been criticized by some,[6] but remains well entrenched in bioethics.

Conflicts

Advance Directives

Courts[1,7,8] and bioethicists[9] have sought to extend the recognized right of competent patients to refuse life-sustaining medical interventions such as mechanical ventilation to patients who are no longer able to participate directly in decisions regarding their medical care. In the intensive care unit, the severity of illness and/or the therapies designed to combat that illness or to provide comfort may interfere with a patient's ability to formulate and communicate preferences regarding medical care. To exercise a right to refuse care, then, new tools and methods needed to be designed in order to give voice to the now mute patient. Advance directives, such as the living will, were felt to fill this role, allowing the previous preferences of the patient to continue to influence medical management after the point that the patient could no longer participate directly. By encouraging patients to explicitly document preferences regarding future care, it was hoped that individual autonomy could guide medical decisions all the way until the very end of life.

Advance directives, however, have failed to impact end-of-life care to any significant degree.[10] The reasons for this failure are myriad, but the most glaring problem of advance directives is ambiguity. Living wills generally contain terms such as "terminal condition," "incurable illness," and "prolonging death" that demand interpretation.

Directives are often completed by individuals at law offices or at home, without any direct communication with medical professionals, leaving questions about the patient's understanding of the risks and benefits of certain interventions and about the patient's intent in completing the document. The document itself, representing the prior preferences of an individual, lacks the same moral weight as a contemporaneous decision by a competent patient.[11]

Caregivers involved in decisions involving the withholding or withdrawal of mechanical ventilation or other forms of life-sustaining therapy must exercise caution when attempting to rely on advance directives to guide care. The ambiguity of these documents requires an exploration of other evidence in support of a particular decision. Such evidence may come in the form of statements made to family members, friends, or primary care providers. The previous goals and values of the patient must be explored in an attempt to understand how the patient would likely choose under the current circumstances. Still, each clinical situation is invariably more complex and nuanced than the patient could have anticipated. Advance care planning, a process by which the patient's values and goals (rather than preferences for particular medical interventions) are elicited in anticipation of a future state in which decision-making capacity is compromised,[12,13] offers more promise for positively influencing end-of-life care than does an advance directive. The value, if any, of current versions of advance directives and ways to improve upon such documents remain the subject of significant contention.

Deciding for Others

In most instances, patients who have lost decision-making capacity will have family members available to help guide medical care. A fair amount of consensus does exist regarding the ethical justification of surrogate decision-making and the manner in which surrogates should attempt to make medical decisions. Individual states determine the priority of family members for surrogate decision-making, but the usual hierarchy begins with the spouse, followed by adult children, parents, and siblings. In virtually all states, a patient has the opportunity to designate an individual, related or not, to fill the role of surrogate decision-maker for matters relating to health care. Such a durable power of attorney for health care (DPAHC) takes priority over other potential surrogate decision-makers (though in many states a court-appointed guardian takes precedence over a DPAHC). Thus, the execution of a DPAHC or equivalent proxy directive allows the selection of an individual felt by the patient to best be able to make medical decisions in the patient's stead. The ethical justification for such a mechanism is straightforward: surrogates, in knowing the patient well, are seen as able to give voice to the patient, essentially acting as a tool by which the individual patient's autonomy can be preserved even when the patient has lost the capacity for autonomous action. The patient, while still competent, would seem to be in the best position to identify the person who will best represent them and, therefore, should be allowed to designate them directly.

Consensus among the courts, bioethicists, and medical practitioners also appears to have been reached. Surrogates, whether a next of kin or a DPAHC, should strive to make decisions in accordance with what they believe the patient would decide if he or she were able to participate directly in the discussion. This approach to surrogate decision-making is designated the "substituted judgement standard." The substituted judgement standard is distinct from other possible manners in which surrogates could decide for patients. For instance, we could instruct a surrogate to choose what he or she, individually, would want under circumstances identical to the patient's, or we could ask the surrogate to assess and act in accordance with the "best interests" of the patient. But using the substituted judgement standard is defended as the best way to respect the autonomy of an individual patient, because the patient's goals and values form the basis for the choice.

The use of substituted judgement by surrogate decision-makers, however, is not without problems. The ability of surrogates to accurately predict what medical interventions an individual patient would want under certain circumstances has been called into question by several studies.[14–16] Surrogates in these studies were not much better than chance at predicting patient choices for medical care in hypothetical clinical scenarios. Such discordance is concerning because it casts doubt on the reliability of substituted judgement in actual clinical situations.

Given this degree of uncertainty about the accuracy of surrogate decisions, then, leaves health care providers in a position of having to independently assess the substituted judgement before deciding whether to act on it. The statement of a family member, for instance, who requests the withdrawal of mechanical ventilation by stating that the patient would "not want to be kept alive" in such a fashion, cannot simply be accepted at face value. The problem with doing so would be quite obvious in certain situations, such as a patient with a good prognosis and a large life insurance policy, where the surrogate's motivations are easily questioned. But even when the surrogate's motives appear honorable, uncertainty remains regarding the accuracy of the judgement.

The courts and ethicists have recognized the possibility that substituted judgements might not always be true representations of a patient's wishes, and have offered a mechanism to prevent abuse and mistakes. This mechanism is borrowed from the law and requires the health care provider to accumulate and evaluate other evidence in support of the substituted judgement prior to assuming its validity.

But medical professionals are not trained to determine the probative value of evidence, nor are they usually familiar with the evidentiary standards (eg, clear and convincing preponderance of evidence) mandated as thresholds for determining the validity of a substituted judgement. Such an approach may work reasonably well for those rare cases of withholding and withdrawing support that reach the courts, but it is extremely cumbersome and problematic in medical practice.

In practice, medical practitioners have been left to develop their own methods for evaluating the decisions made by family members on behalf of incompetent patients.[17] Additional evidence in support of a substituted judgement is usually not sought when the course of action preferred by the family member clearly appears to be in the patient's best interest, while caution requires the search for supporting evidence if the surrogate's decision seems contrary to those interests. So, although surrogate decision-makers remain integral to good patient care, medical practitioners cannot simply abdicate all aspects of medical decision-making to such surrogates. Conflicts, then, will continue to arise in the care of individual patients, though these can be minimized through good communication.[18]

Medical Futility

In the era of ascendancy of patient autonomy, health care providers have increasingly found themselves faced with demands for particular kinds of care that do not appear to be medically appropriate. For instance, the parents of an anencephalic infant may demand continued mechanical ventilation despite no chance of the child surviving past infancy. Likewise, a patient with metastatic lung cancer and impending respiratory failure may demand intubation and mechanical ventilation despite the fact that death is imminent regardless of therapy. Physicians and other caregivers may feel uncomfortable providing care that seems bereft of medical benefit.

The notion of medical futility, then, has been advanced as a concept that would define situations where certain interventions can be withheld from a patient regardless of the patient's preferences.[19] Definitions of futility vary, but all reflect a belief that practitioners can unilaterally identify situations where meaningful survival cannot be achieved. Invoking futility, then, requires no particular knowledge of the patient's values, goals, or preferences. Futility defines an "autonomy-free zone" where decisions may be made unilaterally by medical practitioners, without patient or surrogate input. Futility may be used to describe situations in which continued therapy will not result in survival (quantitative futility), will not produce an acceptable quality of life (qualitative futility), or has no physiologic effect (physiologic futility).

Many professional organizations, including the American Thoracic Society,[20] have recognized the concept of futility and assert the right of medical caregivers to refrain from providing care that they believe is not beneficial. Still, using futility to limit the care of individual patients remains problematic. A central problem remains regarding who should be allowed to determine what is beneficial in a particular case. For instance, medical caregivers may feel that no benefit is provided to a patient with metastatic lung cancer being maintained on mechanical ventilation and, since death is imminent, may view the delivery of such care as futile. The patient or family, however, may see benefit in continued support. For instance, they may feel that life, in any form, is better than death. Or perhaps they are waiting for other family members to arrive and say their goodbyes, making continued survival of the patient a worthwhile goal. Invoking futility in such situations, then, requires such sentiments and goals to be disregarded as not meaningful. Such difficulties have led some authors to argue that only physiologic futility, meaning that the intervention would have no measurable physiologic effects, can be ethically invoked as a reason for unilateral withdrawal of therapy.[21] But invoking physiologic futility cannot alter outcome; if an intervention has no physiologic effect, it does not matter whether it is provided or not. Futility remains useful only if it describes a situation in which an intervention is doing something, but resulting in nothing beneficial. Determination of futility, then, rests on the determination of what constitutes a benefit.

Futility is often invoked out of a sense of frustration on the part of medical practitioners. As such, it may often be used as a "conversation ender" with families perceived as difficult. Almost never is this the optimal course of action. Patience on the part of medical staff and continued efforts of communicating with patients and families will nearly always result in agreement over several days.[18] Futility remains useful as a theoretical concept, but its value in clinical practice remains, and should remain, minimal.

Practical Implications

Although situations involving the withdrawal of life-sustaining therapies, including mechanical ventilation, must continue to be addressed individually, understanding the areas of ethical consensus can help guide the process of withdrawal, and knowledge of current ethical conflicts can help to identify potential pitfalls.

The recognition of a patient's right of refusal of medical interventions sets the stage for discussion with the patient or surrogates regarding the appropriateness of life-sustaining therapies. The ethical equivalence between withholding and withdrawing therapies means that particular interventions should not be withheld simply out of fear that

once they are instituted they cannot be discontinued. For cases where aggressive care no longer seems appropriate, decisions, regarding further therapy are best made in a shared fashion, where the patient or surrogate provides the personal goals and values important for making such a decision, and the medical team provides the assessment of whether the interventions offer any reasonable chance of meeting those goals or respecting those values.

Once a decision has been made that the sole focus of care is on patient comfort, the consensus that all forms of life-sustaining therapy are ethically equivalent dictates that all therapy not necessary for patient comfort be discontinued. Withdrawal of interventions in a piecemeal fashion is generally inappropriate. Withholding pressors but continuing mechanical ventilation in the "comfort care only" situation makes little sense. Graduated withdrawal of a particular therapy may be indicated in some situations in order to ensure that the patient remains comfortable. For instance, the withdrawal of mechanical ventilation can proceed in a stepwise fashion, with decreasing levels of support, in the patient who shows signs of dyspnea or respiratory distress, allowing the titration of narcotics and sedatives designed to alleviate such discomfort. Therapy for pain, discomfort, or dyspnea should never be withheld or underdosed out of fear that such therapy will hasten death. This said, agents that are not necessary for patient comfort and that will certainly hasten death after withdrawal of mechanical ventilation, such as neuromuscular blocking agents, must not be administered prior to the withdrawal of support.

The areas of ethical contention discussed earlier help identify common trouble spots in end-of-life care. The ambiguity of advance directives means that different readers, whether family or medical staff, may interpret the documents differently. All concerned must recognize that such documents alone are virtually never sufficient to determine the course of care. The fact that surrogate decisions do not necessarily reflect the desires of patients demands that medical practitioners attempt to assess the validity of surrogate choices rather than simply accept them at face value. But this check on a surrogate's power for medical decision-making should not be abused in order to advance the choices of the medical provider over those of the patient; the invoking of futility may represent an attempt by a physician to wrest control of decision-making from a patient or surrogate. The ultimate goal of both caregivers and surrogates must be the benefit of the patient. Only by combining the values and preferences of the patient, sometimes knowable only through the appropriate surrogate, with the medical assessment of experienced clinicians can optimal end-of-life decision-making take place.

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Letters

Humidification for Patients with Artificial Airways: More on the HME-Booster

In response to the article, "Humidification for Patients with Artificial Airways" by Richard D Branson [Respir Care 1999; 44(6):630-641], discussing, *inter alia*, the heat and moisture exchanger booster (HME-Booster) made by TomTec, Belgium, we would like to discuss several points that we consider to have been misrepresented.

Mr Branson states that the HME-Booster is "... less efficient." In fact, when used in combination with an HME, the HME-Booster improves absolute and/or relative humidity and temperature delivered by the HME. Tracheal temperature also increases. The HME-Booster heats and humidifies gases, thus increasing the benefits of the HME (R Boiteau MD, J Reigner, A Tenaillon, Hôpital Louise Michel, Evry, France, unpublished data, Sept 1997). The HME-Booster may allow better humidification of the inspired gases in critically ill patients simply, safely, and inexpensively (JM Anthony, N Evans, V Knowles, GR Park, TomTec Belgium, and the John Farman ICU, Addenbrooke's Hospital, Cambridge, UK, unpublished data, Feb 1996).

Mr Branson states that that the heating element is covered with a Gore-Tex membrane, but actually the heating element is in contact with a Gore-Tex membrane through a T-piece connector. Mr Branson states that some of the moisture escapes through the HME. In fact, some of the moisture escapes through the HME *depending on the HME used*. But with the concept of the HME-Booster in which heat and humidity are delivered outside the HME, this limits the escape of humidity through the HME.

Mr Branson states that the water flow is controlled by a pin-hole-sized orifice adjacent to the heating element. However, water flow is controlled by the Gore-Tex membrane of the T-piece connector, the temperature of the heater, and the aluminum grid, which acts as a heat transmitter and sensor. Water from a giving set passes through the orifice in order to saturate the membrane. Concretely, the amount of water output of the HME-Booster is caused by the pore size of the Gore-Tex membrane (0.2 micron), the temperature provided by the PTC (positive temperature control) in the heating element, and the aluminum grid that influences the PTC. The size of the orifice (0.1 mm) does not contribute to the water output. It is merely a channel to supply water to the HME-Booster.

Mr Branson states that "This prevents pooling of excess water." The size of the orifice was designed this way in order to conduct the water precisely between the heating element surface and the membrane. Mr Branson states that the device can add an additional 3–4 mg H_2O/L. But the fact is that the device adds 4–5 mg H_2O/L. The Booster adds on average 3 g H_2O/h, computed according to the following:

Ventilator settings during our tests: tidal volume of 1 L at 10 cycles per minute = 600 L/h

$$3 \text{ g} / 600 \text{ L} = 5 \text{ mg } H_2O/\text{L}$$

32 mg produced by a good quality HME + 5 mg added by the Booster = 37 mg H_2O/L at a temperature of 34° C. This result is close to saturation on absolute humidity. At 34° C, 37.5 mg H_2O/L is needed to reach saturation.

Mr Branson states that the HME-Booster provides a "... small increase in moisture output ...." Actually, the HME-Booster adds a *significant* increase in moisture and temperature. Whilst the HME provides about 80% of heat and moisture, the Booster adds an additional 20% to compensate for the loss.

Georges Gilman
President, TomTec NV
Kapellen
Belgium

The author responds:

I appreciate the interest of the manufacturer in our description of their product. It was not our intention to give explicit details of operation, but rather to provide an overview of the numerous humidification products available to clinicians. I will address each of the points in the manufacturer's letter and attempt to explain my position.

The HME-Booster with a good HME is in fact "less efficient" than the active HME. There is no disputing this fact. Mr Gilman provides anecdotal evidence and cites two unpublished reports to support the successful use of the Booster. Neither lends any evidence to his argument. As was discussed at the conference, humidification is applied in a wide variety of fashions by numerous clinicians. Dr John Lawrence from Australia delivers gas at 100% relative humidity and 41° C, appears to have great success, and sees no reason to change his practice. From Europe and South America we hear reports of investigators who never use anything but an HME, with similar success. These are like bedtime stories, comforting but not scientific evidence. More to the point, an active HME set to deliver 100% relative humidity and 37° C provides 44 mg H_2O/L. By his own admission, Gilman suggests the Booster provides 37.5 mg H_2O/L. Using simple math, the Booster is "less efficient" than the active HME; any other conclusion is simply wrong.

In our brief description regarding the Gore-Tex membrane, the membrane does in fact cover the heating element, through use of a plastic connector. Similarly, the water used is obviously affected by the evaporation of water over the heater. It was my understanding that the narrow orifice was used to prevent excessive water accumulation, which would reduce the efficiency of the Booster. Mr Gilman's comments provide more detail than I had intended, but I concur with his comments.

All HMEs allow water vapor to pass through the medium: otherwise all would be 100% efficient. Adding moisture between the patient and the HME does nothing to prevent escape of moisture through the HME! The Booster adds moisture on inspiration and "loads" the HME during expiration, but even the best HME will lose 20% of the moisture entering the medium. If Mr Gilman means

that the Booster helps prevent total moisture loss from the patient, then he is correct. However, the Booster cannot affect the moisture-conserving capacity of the HME.

The data, once again, provided by Mr Gilman regarding the Booster are unpublished and the methods are not provided. It is difficult to argue the point, except to say that our information is based on an abstract presented at The Society of Critical Care Medicine, following peer review.[1] I believe Mr Gilman has confused water delivered with water used. If you measure the weight change in the water bag, the Booster uses approximately 3 g per hour. However, based on the inspiratory-to-expiratory-time ratio, respiratory rate, and tidal volume, some of this moisture is lost on expiration. Assuming an HME that is 80% efficient, then 5 mg H_2O/L is really 4 mg H_2O (or less) delivered. This is why we depend on independent evaluation by researchers to validate products. It is not sufficient to take the word of the manufacturer with a vested interest in the product, attempting to put the best "spin" on the product's efficiency.

The statement that the Booster provides "a small increase in moisture output" is, again, exactly correct. If the HME provides a moisture output of 32 mg H_2O/L and the Booster provides—let's split the difference and say 4 mg H_2O/L, then the Booster provides 12.5% of the moisture and the HME provides 87.5% of the moisture. I think this certainly supports my contention that the increase is small relative to the total moisture output.

My intention was to describe humidification techniques, and I included the HME-Booster for completeness and to share our laboratory experience. I appreciate the more detailed description of the device provided by Mr Gilman. However, the remainder of the letter is based on unpublished evidence, unknown methodology, and manufacturer bias.

I believe the Booster may have some usefulness in areas where heated humidification is underutilized. It still has not received 510(k) clearance here in the United States. As such, I stand by the statements related to efficiency. Any reader with an unbiased viewpoint will see that these are just quite simply the facts.

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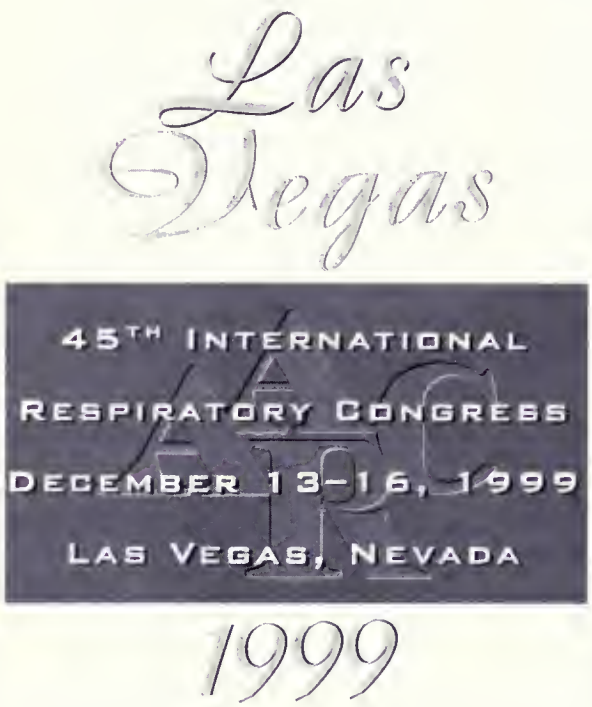
REFERENCE

1. Branson RD, Campbell RS, Johannigman JA, Davis K Jr, Frame SB. A comparison of two novel methods of humidification (abstract). Crit Care Med 1999;27:A70.



Listing and Reviews of Books and Other Media. Note to publishers: Send review copies of books, films, tapes, and software to RESPIRATORY CARE, 600 Ninth Avenue, Suite 702, Seattle WA 98104.

Books, Films, Tapes, & Software

Pediatric Asthma. Shirley Murphy MD and H William Kelly PharmD, Editors (Lung Biology in Health and Disease, Volume 126. Claude Lenfant, Executive Editor.) New York/Basel: Marcel Dekker; 1999. Hardcover, 579 pages. $195.00.

Pediatric Asthma is the 126th volume in the well-known **Lung Biology in Health and Disease** series published by Marcel Dekker. **Pediatric Asthma** is edited by Dr Shirley Murphy and Dr H William Kelley, both international experts in the field of pediatric asthma and asthma pharmacology. Twenty-two contributing authors compose a multidisciplinary team of physicians, research scientists, nurses, and pharmacologists who together have produced a book devoted completely to pediatric asthma. The book is quite comprehensive in its scope. It includes important chapters on the epidemiology and natural history of pediatric asthma as well as the role of allergy in the pathogenesis of asthma and asthma's psychological effects on child growth and development. Other chapters deal with therapy for chronic and acute pediatric asthma, including up-to-date treatment guidelines and algorithms from the 1997 National Heart, Lung, and Blood Institute's "National Asthma Education and Prevention Program Expert Panel Report II: Guidelines for the Diagnosis and Management of Asthma." Finally, specific chapters are devoted to individual pharmacologic agents used to treat pediatric asthma, including β-agonists, theophylline, glucocorticoids, and other anti-inflammatory agents, including leukotriene modifiers. As a multi-disciplinary work dedicated solely to pediatric asthma, the book is appropriate for all health care professionals who spend a large percentage of their time dealing with asthmatic children and their families. Respiratory therapists may be especially interested in chapters on patient education and specific chapters on aerosol delivery, including the pediatric use of metered dose inhalers, nebulizers, and spacers.

The editors have done an admirable job in constructing such a comprehensive book dealing with the most significant respiratory disease in children. Chapters are, in general, extremely well written, and include extensive references to relevant clinical and basic research. The treatment pathways are the most up-to-date from the National Asthma Education and Prevention Program. The book's style is somewhat disjointed, however, which is one of the difficulties in a state-of-the-art book with multiple authors.

Chapter 6, "Chronic Therapy Overview," appears to give a general synopsis of the entire book, with small sections on asthma pathogenesis, pulmonary function testing, diagnosis of asthma, and treatment of asthma with both bronchodilatory and anti-inflammatory medications. This chapter is separated from the one on management of acute severe asthma by the two chapters dealing with the psychology of pediatric asthma and patient education in pediatric asthma. Perhaps the flow of the book would be better if the chronic therapy chapter was contiguous with the one on management of acute severe asthma. In addition, Chapter 10, "Intensive Care Unit Management of Asthma," is short and does not stand well by itself. Chapter 10 should probably have been incorporated into the chapter on management of acute severe asthma.

Each chapter is easy to read, and the figures are well designed and easy to interpret, but there are a few obvious typographical and editorial errors. For instance, the last sentence on page 447 is repeated on the first line of page 448. Also, between pages 448 and 449, there is at least one sentence of specific information missing. The index is relatively short for a book of this size; however, it is fairly detailed and useful. There is also an extensive author index, which helps with identification of manuscripts cited in the text.

In summary, this is a well written, easy to understand, timely, and comprehensive book that covers all aspects of pediatric asthma, from epidemiology to treatment to education. As such, it is the most complete and up-to-date reference in pediatric asthma published to date. I would suggest this book to any health care professional whose practice deals specifically with asthma in the pediatric age group.

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Advances in Modeling and Control of Ventilation Richard L Hughson, David A Cunningham, and James Duffin, Editors. (Advances in Experimental Medicine and Biology, Volume 450.) New York/London: Plenum Press; 1998. Hardcover, illustrated, 241 pages. $105.00.

This book contains the proceedings of the Canadian Conference on Modeling and Control of Ventilation, held in Huntsville, Ontario, Canada, on September 17–21, 1997. This conference was the seventh in a series of meetings that began in Oxford, England, in 1971 and has subsequently been held every 3 or 4 years. Each of these meetings has been attended by researchers interested in developing an integrative view of respiratory control in health and disease. The hallmark of these conferences has been the forum they have created for intellectual exchange and interaction between respiratory physiologists trained in the life sciences and respiratory researchers trained in engineering and mathematics. This "spirit" can be traced back to the "founding fathers" of the Oxford series, Dr Dan Cunningham and Dr Richard Herczynski, eminent figures in their respective fields of respiratory physiology and physiologic modeling. The rustic, retreat-like settings in which meetings have been held provide the participants uninterrupted access to one another and allow graduate students to mingle casually with some of the world's most eminent respiratory physiologists. In keeping with previous conferences, the quality of the research presented at this latest meeting was topnotch. The book contains 37 original research contributions, with the chapters ranging from 3 to 8 pages. The authorship is truly international, with representation from the United States, Canada, Japan, United Kingdom, Germany, and the Netherlands.

The book covers a diverse spectrum of topics that can be roughly classified into respiratory neurobiology, integrative responses to chemoreflex stimulation and other perturbations, respiratory control during exercise, and improved respiratory measurement techniques. The neural category includes, among others, studies on the synaptic connections to the phrenic motor neurons, the phrenic nerve response to glutaminergic receptor blockade, and the relationship

between bronchoconstriction and the activation of rapidly-adapting receptors in the airways. The integrative response category includes several studies of the ventilatory effects of hypoxia under a variety of conditions: following passive hyperventilation, with β-blockade, and during low-dosage sevoflurane anesthesia administration. There are also several interesting studies of respiratory control during exercise. One shows that considerable ventilatory hyperpnea can be generated in subjects under hypnosis who are made to *imagine* that they are exercising. Another study systematically explores the phase relations between rhythmical forearm movements and breathing.

By and large, the topics covered in this book are of greatest value to the basic researcher. However, a number of articles cover material of a more practical nature that may be of interest to the respiratory therapist, nurse, or physician. For instance, the chapter by Tuck and Remmers compares 3 methods of assessing awake and asleep respiratory impedance. The first method assumes a linear fit between resistive pressure and inspiratory air flow; the second method assumes the parabolic relationship or "Rohrer's equation"; and the third method uses a rectangular hyperbolic expression. The coefficients of these models are also compared to air flow resistance measured at mid-inspiration (a commonly employed technique) and the average resistance, estimated by averaging the instantaneous resistance throughout the inspiration. In breaths with no flow limitation, the linear model provided the best measure of respiratory impedance. However, in breaths with flow limitation, the rectangular hyperbola model worked best. Most significantly, the researchers found average resistance to be strongly correlated to the coefficients of both linear and rectangular hyperbola models, implying that average resistance is useful as a parameter for characterizing mechanical load on the respiratory system during flow-limited and non-flow-limited conditions.

In another chapter, Kroumov and colleagues present a method for automatically controlling the oxygen supply to patients with chronic obstructive pulmonary disease. The basis for their adaptive control scheme is somewhat technical, being deeply rooted in engineering control theory. However, the basic idea is that a model describing oxygen exchange in the patient is adaptively estimated and used to adjust the inhaled oxygen content in such a way as to maintain arterial oxygen saturation near the desired level with minimal fluctuations. Another advantage of this scheme is that fluctuations in administered oxygen flow are decreased.

In conclusion, this book is a useful reference source for those interested in a broad overview of state-of-the-art developments in respiratory control research. Despite the diversity of topics, there is considerable thematic coherence among the groups of articles. For a research volume, it is highly readable. Although it is of limited direct value to the respiratory therapist, nurse, or physician, this book would make a good addition to the library of a respiratory care department with an active research program.

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Health Devices Sourcebook 1999: Medical Product Purchasing Directory with Official Universal Medical Device Nomenclature System. Plymouth Meeting, Pennsylvania: ECRI; 1998. Hardback, 3,036 pages. $395.00.

Healthcare Standards 1999 Official Directory. Plymouth Meeting, Pennsylvania: ECRI; 1998. Hardback, 2,588 pages. $395.00.

The **Health Devices Sourcebook** is intended for a wide range of health care service professionals, including biomedical engineers, clinical engineers, materials management directors, purchasing directors, physicians, and others. Medical device companies and government agencies worldwide also use it. Professionals use this directory to find out which companies handle particular products, to locate manufacturing companies, to research purchasing decisions, to learn what other products are available, to find out more about their competition, and to locate companies that provide special services for medical equipment.

The book is organized into the following sections: product categories listed alphabetically; product categories listed by specialty; product listings by type; trade names; product lines (manufacturer's address, World Wide Web address, business type, contact personnel, number of employees, types of products sold); manufacturers' addresses listed alphabetically; manufacturers' addresses listed by state; equipment services; service company profiles; service company addresses listed alphabetically; master company list; executive contacts; numerical listings by manufacturers and service companies; numerical listings by product category (matches product category to 5-digit Universal Medical Device Codes, which are used to establish literature filing and computer-based data retrieval systems and can be used on purchase requisitions so that quotations can be obtained from all qualified suppliers; categories are based on the international standard controlled vocabulary for medical device classification used in regulatory and procurement systems worldwide).

In addition, there are brief sections explaining what hospitals should know about medical device regulations, medical device selection and acquisition, and buying and selling used medical equipment. The section on medical device acquisition has a particularly helpful list of questions buyers should ask.

The **Healthcare Standards Directory** is an easy-to-use, comprehensive guide to health care standards, practice guidelines, and other official documents. It is part of an ongoing program to identify, obtain, classify, and publish a diverse collection of health care information that is of practical importance to professionals in health care, insurance, law, and government, as well as health care consumers, librarians, and researchers.

The **Directory** includes standards issued by medical societies, professional associations, government agencies, and other health-related organizations. The standards cover an exhaustive range of subjects, from guidelines on how to perform a specific procedure to implementing legally mandated workplace safety measures. The need for this type of directory exists because many groups are scrutinizing whether patient care meets professionally recognized standards of practice. These groups include the United States federal government, through its Medicare program, and the United States Agency for Health Care Policy and Research, which sponsors the development of clinical practice guidelines in a variety of specialty areas. The agency also acts as a clearinghouse for: guidelines available on the World Wide Web (www.ahcpr.gov); business and consumer groups; third-party payers and managed care organizations whose technology assessments underpin reimbursement decisions; legal professionals who must prove whether treatments administered meet the applicable standard of care; malpractice

insurance companies interested in helping practitioners minimize risk and who sometimes reduce premiums when there is agreement to follow established standards; health care executives, risk managers, and quality assurance directors, who strive to ensure safe patient care; accreditation organizations that examine patient outcomes in light of clinical guidelines; health care practitioners interested in keeping abreast of changes in their specialty areas; and patients interested in knowing they will receive high-quality care.

The **Healthcare Standards Directory** contains: a cross-referenced *keyword index* based on natural language expressions as well as controlled vocabularies, including the United States National Library of Medicine's Medical Subject Headings; complete *citations* to standards, legislation, and referenced articles; an alphabetical listing (including contact information) of *organizations* issuing health care standards, along with the title of the standard the organization issues and bibliographic, price, and ordering information; an alphabetical listing of *United States federal agencies* that have issued health-related regulations; a listing of *United States state health-related laws* and regulations, including the title and citation of each regulation; an alphabetical listing of *abbreviations* for each organization; a listing of complete address and telephone information for all organizations and federal and state agencies.

I found it particularly helpful that the **Directory** included not only the American Association for Respiratory Care Clinical Practice Guidelines, but also the consensus statements, position statements, and special reports dating back to 1973.

Both the **Healthcare Standards 1999 Official Directory** and the **Health Devices Sourcebook** are well organized reference texts that are produced in the high quality format typical of ECRI publications.

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Contagion and Confinement: Controlling Tuberculosis Along the Skid Road. Barron H Lerner. Baltimore/London: The Johns Hopkins University Press; 1998. Hardcover, illustrated, 243 pages. $42.50.

A middle-aged woman from Korea recently went to the Seattle-King County tuberculosis (TB) clinic for evaluation of an abnormal immigration chest radiograph that suggested prior TB disease. The films showed evidence of the state-of-the-art treatment she had received in Korea as a teenager during the 1960s, including thoracoplasty and the insertion of many staple-like wires under the skin of her upper chest. The latter was a kind of folk treatment. The former, as she described it, was administered at the end of a year of medical treatment with isoniazid and PAS (*para*-aminosalicylic acid), when it was determined that, due to her age and suspected noncompliance with medications, collapsing the tuberculous section of her lung would reduce the chances of later relapse. This patient, like many others, is a living demonstration of medical and social elements of medical history, including interventions that were appropriate in another era but that might be considered malpractice if administered today.

Barron Lerner's recent book, **Contagion and Confinement: Controlling Tuberculosis Along the Skid Road**, presents a fascinating account of the medical and social history of TB control in the United States, as exemplified by the experiences of one representative community in and around Seattle, Washington, over the past 100 years. Lerner highlights many of the controversies that mark the history of the treatment of TB through successive eras, how they were resolved, and how they often return. His perspective as a historian helps illustrate precedents in TB treatment going back 30, 50, and 100 years that may serve as useful lessons for modern TB control workers.

The book extensively documents the history of TB control efforts in Seattle and King County, dating back to the time of the discovery of the tubercle bacillus by Robert Koch and the inception of the sanatorium era. It clearly shows how the developments in one community illustrate concurrent trends across the United States. In addition to outlining some of the purely medical developments, he shows how TB controllers have addressed the complex interactions between the disease and other health-related conditions of those affected. During the eras he describes, major ancillary issues included alcoholism, poverty, and homelessness, all of which increase the difficulties of treating TB. Lerner's descriptions of how public health authorities, academic researchers, and concerned citizens have addressed these complex interactions during the different eras of this century are fascinating and well documented. TB in the United States continues to be largely a disease of marginalized communities and of persons with other complex medical and psychosocial problems, including substance abuse, mental illness, and immigration. While particular factors complicating the disease change, the need to confront them concurrently with diagnosis and treatment persists.

The complexity of the disease and the persistent inadequacies of modern treatments continue to compel modern TB controllers to consider many factors besides pure medical treatment in control efforts. The historical narrative of **Contagion and Confinement** shows the diversity of approaches taken by our predecessors as they dealt with the medical, social, political, and ethical issues of TB treatment. This story challenges the reader to consider how best to learn from a range of carefully developed approaches that were models for their successive eras.

As the title implies, the focus of **Contagion and Confinement** is on the ethical dilemmas posed by the involuntary detention of homeless alcoholics during their treatment for TB. While detention is an important topic with major relevance for modern TB work and deserves the historical study it receives in this book, it is unfortunate that Lerner develops this focus into the organizing theme of the book. The lessons in the text are not nearly as confined as the title implies. Furthermore, contrary to Lerner's assertions, attempts to detain certain patients for the duration of treatment were not unreasonable in the context of the end of the sanatorium era. A contemporary reader who understands the pathophysiology of TB could easily conclude that some of the detentions Lerner describes as excessive violations of individual rights were in fact appropriate. The recent resurgence of TB in the United States and the emergence of multi-drug-resistant organisms in noncompliant patients should remind clinicians and others concerned with public health of the crucial importance of fully completing a course of treatment. To ensure completion of therapy, many modern TB control programs have more subtle and more effective case management tools such as outpatient directly-observed therapy incentives, and social services that make detention a relatively uncommon last resort. However, the success of modern approaches in a modern

context does not detract from the value or the legitimacy of other approaches in an earlier medical and social context.

Lerner judges TB controllers of an earlier era for what might be transgressions if their methods were practiced today. He explicitly condemns the detention practices of 30–40 years ago and thoracoplasty as it was used for the patient described earlier, largely based on a presumption of future noncompliance with drug treatment, and might even condemn the use of wires under the skin as a dangerous violation of individual rights. One wonders how a future historian of medical ethics will judge current treatments from the perspective of a time when they are outdated by much more effective treatments.

Contagion and Confinement may misleadingly encourage polemicists of due-process and individual rights who might minimize the public health threat of this dangerous infectious disease. Fortunately for the reader who is not dissuaded by its title, structure, or explicit message, it presents, in a very readable and enjoyable manner, a broad and well-documented history of combined medical and psychosocial approaches to TB control. Such combinations remain necessary for the treatment of a complex and too often underestimated disease. This book will provide enlightening and useful reading for students of medical history.

Stefan Goldberg MD
Tuberculosis Clinic
Seattle-King County Department of Public Health
Seattle, Washington

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Anyone wishing to donate an item to the auction may do so by contacting Norma Hernandez of the ARCF executive office at 972-243-2272, or by e-mail at hernandez@aarc.org

AARC & AFFILIATES

November 15—*Traverse City, Michigan*

The AARC Spirometry Course will be offered by TechEd at the Munson Medical Center. It has been approved by the AARC for seven hours of CRCE credit.
Contact: For more information, call Karen Kain at (616) 935-6736.

November 16—*Teleconference*

After viewing a tape of the eighth installment of the AARC's 1999 "Professor's Rounds" series, "New Developments in Respiratory Drugs, Medications, and Delivery Devices," participate in a live telephone question-and-answer session (11:30–12 noon CT) and receive one CRCE credit hour.
Contact: To receive the 90-minute videotape and register for the teleconference, call the AARC at (972) 243-2272.

December 13–16—*Las Vegas, Nevada*

The AARC's 45th International Respiratory Congress is scheduled for Dec. 13–16 (Monday through Thursday) at the Las Vegas Convention Center. Sessions appealing to all levels of health care providers will be offered, with CRCE credit available. Exhibits by international manufacturers of cardiopulmonary equipment will be featured. See the AARC web site for additional information: **www.aarc.org**.

March 15-17, 2000—*Lake Tahoe, Nevada*

The Greater Bay Area Chapter of the California Society for Respiratory Care will host their 21st annual conference at Caesars Lake Tahoe. "Tahoe 2000" will offer 12 hours of continuing education credit.
Contact: For more information, call (925) 866-6643 or access their web site at **www.csrc.org.**

Other Meetings

October 31–November 4—*Chicago, Illinois*

The American College of Chest Physicians will host their 65th Annual International Scientific Assembly at the Lakeside Center. For information, contact Member Services at (800) 343-2227, fax (847) 498-5460, or **www.chestnet.org**.

April 1-7, 2000—*Miami, Florida*

Miami Children's Hospital and the Ventilation Assisted Children's Center (VACC) are hosting their annual camp for ventilation-assisted children and their families. The campsite is A.D. Barnes Park, a 62-acre park located two miles from Miami Children's Hospital. Facilities include an air-conditioned lodge, two air-conditioned bunkhouses, and wheelchair-accessible swimming pool, playground, and nature trail. The VACC Camp treats families with children dependent on oxygen, a tracheostomy, ventilator, CPAP, or bi-level PAP to a week of fun and adventure in the company of their peers.
Contact: If you know of eligible, interested families, have them contact Camp Director Dr. Moises Simpeer or Bela Floretin at (305) 662-8380, ext. 4610, or (305) 662-8222. Applications will be accepted through Jan. 15, 2000.

News releases about new products and services will be considered for publication in this section. There is no charge for these listings. Send descriptive release and glossy black and white photographs to RESPIRATORY CARE, New Products & Services Dept, 11030 Ables Lane, Dallas TX 75229-4593. The Reader Service Card can be found at the back of the Journal.

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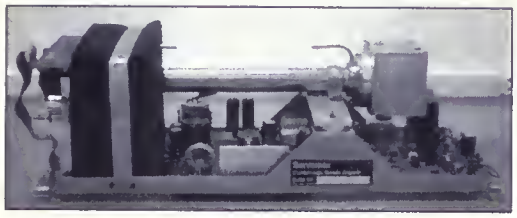

Gas Filter Correlation Technology. Servomex introduces its advanced gas filter correlation infrared technology, Gfx. The company says Gfx provides a selection of gas measurements from part per million to percent levels and that by replacing optical filter with cuvettes filled with gas, the technology increases the specificity and sensitivity of an infrared analyzer. Servomex says it uses Gfx technology in both its Xendos and Xentra series of gas analyzers and that measurements include carbon monoxide, carbon dioxide, nitric oxide, hydrochloric acid, sulfur dioxide, and nitrous oxide. For more information from Servomex, circle number 165 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

Portable Monitors. GE Marquette Medical Systems introduces its new Dash® 2000 and Dash® 3000 monitors. According to company press materials, the monitors offers a combination of in-house transport and bedside use. The company says the Dash 2000 is designed for noninvasive monitoring needs during transport and at the bedside in settings like ambulatory surgery, special procedure rooms, and medical imaging departments. They describe the Dash 3000 as ideal for mid-to-high acuity settings needed in emergency departments, ORs and ICUs. GE Marquette Medical Systems says the monitors, which weigh only 12 lbs, offer a 2-5 hour extended battery life and have been "drop tested" for real-world durability. For more information from GE Marquette Medical Systems, circle number 166 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

Ventilator. Pulmonetic Systems Inc, has announced that its new LTV 1000 ventilator has received 510(k) clearance for continuous life supporting ventilation in institutional and transport settings as well as in the home. A company press release says the device is intended to provide mechanical ventilation for pediatric and adult patient in a hospital or healthcare facility and that it can be used for intra- or inter-facility transport. Pulmonetic says the LTV 1000 is completely self contained, weighs less than 13 pounds, contains its own battery source, and does not require compressed air. The company also says approval for the device for homecare use is pending. For more information from Pulmonetic Systems, Inc., circle number 167 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

OTC Peak Flow Meter. Monaghan Medical Corporation has announced that the TruZone™ Peak Flow Meter is now available for over-the-counter sale. The company says that receiving FDA 510(k) clearance to market the device without prescription labeling is an industry "first." Monaghan says the TruZone™ Peak Flow Meter meets the National Asthma Education and Prevention Program guidelines and the American Thoracic Society Standardization of Spirometry. Company literature describes the device as "one size fits all," appropriate for patients of all ages and comes with a one year unconditional guarantee. For more information from Monaghan Medical Corporation Inc, circle number 168 on the reader service card in this issue, or send your request electronically via "Advertisers Online" at http://www.aarc.org/buyers_guide/

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Triage unit sequence #

A. Patient information

1. Patient identifier
In confidence

2. Age at time of event:
or
Date of birth:

3. Sex
☐ female
☐ male

4. Weight
____ lbs
or
____ kgs

B. Adverse event or product problem

1. ☐ Adverse event and/or ☐ Product problem (e.g., defects/malfunctions)

2. Outcomes attributed to adverse event (check all that apply)
☐ death ____ (mo/day/yr)
☐ life-threatening
☐ hospitalization – initial or prolonged
☐ disability
☐ congenital anomaly
☐ required intervention to prevent permanent impairment/damage
☐ other: ____

3. Date of event (mo/day/yr)

4. Date of this report (mo/day/yr)

5. Describe event or problem

6. Relevant tests/laboratory data, including dates

7. Other relevant history, including preexisting medical conditions (e.g., allergies, race, pregnancy, smoking and alcohol use, hepatic/renal dysfunction, etc.)

C. Suspect medication(s)

1. Name (give labeled strength & mfr/labeler, if known)
#1
#2

2. Dose, frequency & route used
#1
#2

3. Therapy dates (if unknown, give duration) from/to (or best estimate)
#1
#2

4. Diagnosis for use (indication)
#1
#2

5. Event abated after use stopped or dose reduced
#1 ☐ yes ☐ no ☐ doesn't apply
#2 ☐ yes ☐ no ☐ doesn't apply

6. Lot # (if known)
#1
#2

7. Exp. date (if known)
#1
#2

8. Event reappeared after reintroduction
#1 ☐ yes ☐ no ☐ doesn't apply
#2 ☐ yes ☐ no ☐ doesn't apply

9. NDC # (for product problems only)
– –

10. Concomitant medical products and therapy dates (exclude treatment of event)

D. Suspect medical device

1. Brand name

2. Type of device

3. Manufacturer name & address

4. Operator of device
☐ health professional
☐ lay user/patient
☐ other: ____

5. Expiration date (mo/day/yr)

6.
model # ____
catalog # ____
serial # ____
lot # ____
other # ____

7. If implanted, give date (mo/day/yr)

8. If explanted, give date (mo/day/yr)

9. Device available for evaluation? (Do not send to FDA)
☐ yes ☐ no ☐ returned to manufacturer on ____ (mo/day/yr)

10. Concomitant medical products and therapy dates (exclude treatment of event)

E. Reporter (see confidentiality section on back)

1. Name & address

phone #

2. Health professional?
☐ yes ☐ no

3. Occupation

4. Also reported to
☐ manufacturer
☐ user facility
☐ distributor

5. If you do NOT want your identity disclosed to the manufacturer, place an " X " in this box. ☐

PLEASE TYPE OR USE BLACK INK

FDA

Mail to: MEDWATCH
5600 Fishers Lane
Rockville, MD 20852-9787

or FAX to:
1-800-FDA-0178

FDA Form 3500 1/96)

Submission of a report does not constitute an admission that medical personnel or the product caused or contributed to the event.

ADVICE ABOUT VOLUNTARY REPORTING

Report experiences with:

- medications (drugs or biologics)
- medical devices (including in-vitro diagnostics)
- special nutritional products (dietary supplements, medical foods, infant formulas)
- other products regulated by FDA

Report SERIOUS adverse events. An event is serious when the patient outcome is:

- death
- life-threatening (real risk of dying)
- hospitalization (initial or prolonged)
- disability (significant, persistent or permanent)
- congenital anomaly
- required intervention to prevent permanent impairment or damage

Report even if:

- you're not certain the product caused the event
- you don't have all the details

Report product problems – quality, performance or safety concerns such as:

- suspected contamination
- questionable stability
- defective components
- poor packaging or labeling
- therapeutic failures

How to report:

- just fill in the sections that apply to your report
- use section C for all products except medical devices
- attach additional blank pages if needed
- use a separate form for each patient
- report either to FDA or the manufacturer (or both)

Important numbers:

- 1-800-FDA-0178 to FAX report
- 1-800-FDA-7737 to report by modem
- 1-800-FDA-1088 to report by phone or for more information
- 1-800-822-7967 for a VAERS form for vaccines

If your report involves a serious adverse event with a device and it occurred in a facility outside a doctor's office, that facility may be legally required to report to FDA and/or the manufacturer. Please notify the person in that facility who would handle such reporting.

Confidentiality: The patient's identity is held in strict confidence by FDA and protected to the fullest extent of the law. The reporter's identity, including the identity of a self-reporter, may be shared with the manufacturer unless requested otherwise. However, FDA will not disclose the reporter's identity in response to a request from the public, pursuant to the Freedom of Information Act.

The public reporting burden for this collection of information has been estimated to average 30 minutes per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to:

DHHS Reports Clearance Office
Paperwork Reduction Project (0910-0291)
Hubert H. Humphrey Building, Room 531-H
200 Independence Avenue, S.W.
Washington, DC 20201

"An agency may not conduct or sponsor, and a person is not required to respond to, a collection of information unless it displays a currently valid OMB control number."

Please do NOT return this form to either of these addresses.

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
Public Health Service • Food and Drug Administration

FDA Form 3500-back

Please Use Address Provided Below – Just Fold In Thirds, Tape and Mail

Department of Health and Human Services
Public Health Service
Food and Drug Administration
Rockville, MD 20857

Official Business
Penalty for Private Use $300

NO POSTAGE NECESSARY IF MAILED IN THE UNITED STATES OR APO/FPO

BUSINESS REPLY MAIL
FIRST CLASS MAIL PERMIT NO. 946 ROCKVILLE, MD

POSTAGE WILL BE PAID BY FOOD AND DRUG ADMINISTRATION

MEDWATCH
The FDA Medical Products Reporting Program
Food and Drug Administration
5600 Fishers Lane
Rockville, MD 20852-9787

American Association for Respiratory Care

MEMBERSHIP APPLICATION

Please read the eligibility requirements for each of the classifications in the right-hand column, then complete the applicable section. All information requested below must be provided, except where indicated as optional. See other side for more information and fee schedule. Please sign and date application on reverse side and type or print clearly. Processing of application takes approximately 15 days.

- ☐ Active
- Associate
  - ☐ Foreign
  - ☐ Physician
  - ☐ Industrial
- ☐ Special
- ☐ Student

Last Name _____

First Name _____

Social Security No. _____

Home Address _____

City _____

State _____ Zip __ __ __ __ __ — __ __ __ __

Phone No. (_____) _____

Primary Job Responsibility (check one only)

- ☐ Technical Director
- ☐ Assistant Technical Director
- ☐ Pulmonary Function Specialist
- ☐ Instructor/Educator
- ☐ Supervisor
- ☐ Staff Therapist
- ☐ Staff Technician
- ☐ Rehabilitation/Home Care
- ☐ Medical Director
- ☐ Sales
- ☐ Student
- ☐ Other, specify _____

Type of Business

- ☐ Hospital
- ☐ Skilled Nursing Facility
- ☐ DME/HME
- ☐ Home Health Agency
- ☐ Educational Institution
- ☐ Manufacturer or supplier
- ☐ Other, specify _____

Date of Birth (optional) _____ Sex (optional) _____

U.S. Citizen? ____ Yes ____ No

Have you ever been a member of the AARC? _____

If so, when? From _____ to _____

Preferred mailing address: ☐ Home ☐ Business

For office use only

FOR ACTIVE MEMBER

An individual is eligible if he/she lives in the U.S. or its territories or was an Active Member prior to moving outside its borders or territories, and meets ONE of the following criteria: (1) is legally credentialed as a respiratory care professional if employed in a state that mandates such, OR (2) is a graduate of an accredited educational program in respiratory care, OR (3) holds a credential issued by the NBRC. An individual who is an AARC Active Member in good standing on December 8, 1994, will continue as such provided his/her membership remains in good standing.

PLEASE USE THE ADDRESS OF THE LOCATION WHERE YOU PERFORM YOUR JOB, NOT THE CORPORATE HEADQUARTERS IF IT IS LOCATED ELSEWHERE.

Place of Employment _____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Medical Director/Medical Sponsor _____

FOR ASSOCIATE OR SPECIAL MEMBER

Individuals who hold a position related to respiratory care but do not meet the requirements of Active Member shall be Associate Members. They have all the rights and benefits of the Association except to hold office, vote, or serve as chair of a standing committee. The following subclasses of Associate Membership are available: Foreign, Physician, and Industrial (individuals whose primary occupation is directly or indirectly devoted to the manufacture, sale, or distribution of respiratory care equipment or supplies). Special Members are those not working in a respiratory care-related field.

PLEASE USE THE ADDRESS OF THE LOCATION WHERE YOU PERFORM YOUR JOB, NOT THE CORPORATE HEADQUARTERS IF IT IS LOCATED ELSEWHERE.

Place of Employment _____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

FOR STUDENT MEMBER

Individuals will be classified as Student Members if they meet all the requirements for Associate Membership and are enrolled in an educational program in respiratory care accredited by, or in the process of seeking accreditation from, an AARC-recognized agency.

SPECIAL NOTICE — Student Members do not receive Continuing Respiratory Care Education (CRCE) transcripts. Upon completion of your respiratory care education, continuing education credits may be pursued upon your reclassification to Active or Associate Member.

School/RC Program _____

Address _____

City _____

State _____ Zip __ __ __ __ __ - __ __ __ __

Phone No. (_____) _____

Length of program

- ☐ 1 year
- ☐ 2 years
- ☐ 4 years
- ☐ Other, specify _____

Expected Date of Graduation *(REQUIRED INFORMATION)*

Month _____ Year _____

American Association for Respiratory Care • 11030 Ables Lane • Dallas, TX 75229-4593 • (972) 243-2272 • Fax (972) 484-2720

American Association for Respiratory Care MEMBERSHIP APPLICATION

Demographic Questions

We request that you answer these questions in order to help us design services and programs to meet your needs.

Check the Highest Degree Earned

- ☐ High School
- ☐ RC Graduate Technician
- ☐ Associate Degree
- ☐ Bachelor's Degree
- ☐ Master's Degree
- ☐ Doctorate Degree

Number of Years in Respiratory Care

- ☐ 0-2 years
- ☐ 3-5 years
- ☐ 6-10 years
- ☐ 11-15 Years
- ☐ 16 years or more

Job Status

- ☐ Full Time
- ☐ Part Time

Credentials

- ☐ RRT
- ☐ CRT
- ☐ Physician
- ☐ CRNA
- ☐ RN
- ☐ LVN/LPN
- ☐ CPFT
- ☐ RPFT
- ☐ Perinatal/Pediatric

Salary

- ☐ Less than $10,000
- ☐ $10,001-$20,000
- ☐ $20,001-$30,000
- ☐ $30,001-$40,000
- ☐ $40,000 or more

PLEASE SIGN

I hereby apply for membership in the American Association for Respiratory Care and have enclosed my dues. If approved for membership in the AARC, I will abide by its bylaws and professional code of ethics. I authorize investigation of all statements contained herein and understand that misrepresentations or omissions of facts called for is cause for rejection or expulsion.

A yearly subscription to RESPIRATORY CARE journal and *AARC Times* magazine includes an allocation of $11.50 from my dues for each of these publications.

NOTE: Contributions or gifts to the AARC are not tax deductible as charitable contributions for income tax purposes. However, they may be tax deductible as ordinary and necessary business expenses subject to restrictions imposed as a result of association lobbying activities. The AARC estimates that the nondeductible portion of your dues — the portion which is allocable to lobbying — is 26%.

Signature _____

Date _____

Membership Fees

Payment must accompany your application to the AARC. Fees are for 12 months. (NOTE: Renewal fees are $75.00 Active, Associate-Industrial or Associate-Physician, or Special status; $90.00 for Associate-Foreign status; and $45.00 for Student status).

☐ Active	$ 87.50
☐ Associate (Industrial or Physician)	$ 87.50
☐ Associate (Foreign)	$102.50
☐ Special	$ 87.50
☐ Student	$ 45.00
TOTAL	$_____

Specialty Sections

Established to recognize the specialty areas of respiratory care, these sections publish a bi-monthly newsletter that focuses on issues of specific concern to that specialty. The sections also design the specialty programming at the national AARC meetings.

☐ Adult Acute Care Section	$15.00
☐ Education Section	$20.00
☐ Perinatal-Pediatric Section	$15.00
☐ Diagnostics Section	$15.00
☐ Continuing Care-Rehabilitation Section	$15.00
☐ Management Section	$20.00
☐ Transport Section	$15.00
☐ Home Care Section	$15.00
☐ Subacute Care Section	$15.00
TOTAL	$_____

GRAND TOTAL = Membership Fee plus optional sections $_____

- ☐ Total Amount Enclosed/Charged $_____
- ☐ Please charge my dues (see below)

To charge your dues, complete the following:

- ☐ MasterCard
- ☐ Visa

Card Number

— — — — — — — — — — — — — — — —

Card Expires _____/_____

Signature _____

Mail application and appropriate fees to:

American Association for Respiratory Care • 11030 Ables Lane • Dallas, TX 75229-4593 • [972] 243-2272 • Fax [972] 484-2720

call for abstracts

RESPIRATORY CARE • OPEN FORUM 2000

The American Association for Respiratory Care and its science journal, RESPIRATORY CARE, invite submission of brief abstracts related to any aspect of cardiorespiratory care. The abstracts will be reviewed, and selected authors will be invited to present posters at the OPEN FORUM during the AARC International Respiratory Congress in Cincinnati, Ohio, October 7-10, 2000. Accepted abstracts will be published in the August 2000 issue of RESPIRATORY CARE. Membership in the AARC is not required for participation. All accepted abstracts are automatically considered for ARCF research grants.

SPECIFICATIONS—READ CAREFULLY!

An abstract may report **(1) an original study, (2) the evaluation of a method, device or protocol, or (3) a case or case series.** Topics may be aspects of adult acute care, continuing care/rehabilitation, perinatology/pediatrics, cardiopulmonary technology, or health care delivery. The abstract may have been presented previously at a local or regional—but not national—meeting and should not have been published previously in a national journal. The abstract will be the only evidence by which the reviewers can decide whether the author should be invited to present a poster at the OPEN FORUM. Therefore, *the abstract must provide all important data, findings, and conclusions*. Give specific information. Do not write such general statements as "Results will be presented" or "Significance will be discussed."

ESSENTIAL CONTENT ELEMENTS

Original study. Abstract *must* include (1) Background: statement of research problem, question, or hypothesis; (2) Method: description of research design and conduct in sufficient detail to permit judgment of validity; (3) Results: statement of research findings with quantitative data and statistical analysis; (4) Conclusions: interpretation of the meaning of the results.

Method, device, or protocal valuation. Abstract *must* include (1) Background: identification of the method, device, or protocol and its intended function; (2) Method: description of the evaluation in sufficient detail to permit judgment of its objectivity and validity; (3) Results: findings of the evaluation; (4) Experience: summary of the author's practical experience or a lack of experience; (5) Conclusions: interpretation of the evaluation and experience. Cost comparisons should be included where possible and appropriate.

Case report. Abstract *must* report a case that is uncommon or of exceptional educational value and must include (1) Introduction: relevant basic information important to understanding the case. (2) Case Summary: patient data and response, details of interventions. (3) Discussion: content should reflect results of literature review. The author(s) should have been actively involved in the case and a case-managing physician must be a co-author or must approve the report.

FORMAT AND TYPING INSTRUCTIONS

Accepted abstracts will be photographed and reduced by 40%; therefore, the size of the original text should be *at least* 10 points. A font like Helvetica or Times makes the clearest reproduction. The first line of the abstract should be the title in all capital letters. Title should explain content. Follow title with names of all authors (including credentials), institution(s), and location; underline presenter's name. Type or electronically print the abstract *single spaced in one paragraph on a clean sheet of paper, using margins set so that the abstract will fit into a box no bigger than 18.8 cm (7.4") by 13.9 cm (5.5"), as shown on the reverse of this page.* Insert only one letter space between sentences. Text submission on diskette is allowed but must be accompanied by a hard copy. *Data may be submitted in table form, and simple figures may be included provided they fit within the space allotted. No figure, illustration, or table is to be attached to the abstract form.* Provide all author information requested. Standard abbreviations may be employed without explanation; new or infrequently used abbreviations should be spelled out on first use. Any recurring phrase or expression may be abbreviated, if it is first explained. Check the abstract for (1) errors in spelling, grammar, facts, and figures; (2) clarity of language; and (3) conformance to these specifications. An abstract not prepared as requested may not be reviewed. Questions about abstract preparation may be telephoned to Linda Barcus at (972) 406-4667.

Early Deadline Allowing Revision. Authors may choose to submit abstracts early. Abstracts postmarked by February 29, 2000 will be reviewed and the authors notified *by letter only* to be mailed by March 31, 2000. Rejected abstracts will be accompanied by a written critique that should, in many cases, enable authors to revise their abstracts and resubmit them by the Final Deadline (April 28, 2000).

Final Deadline. The mandatory Final Deadline is April 28, 2000 (postmark). Authors will be notified of acceptance or rejection *by letter only*. These letters will be mailed by July 12, 2000.

Mailing Instructions. Mail (Do not fax!) 2 clear copies of the completed abstract form, diskette (if possible), and a stamped, self-addressed postcard (for notice of receipt) to:

2000 RESPIRATORY CARE OPEN FORUM
11030 Ables Lane
Dallas TX 75229-4593

submit your OPEN FORUM abstract electronically
visit www.rcjournal.com

RESPIRATORY CARE OPEN FORUM 2000 Abstract Form

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13.9 cm or 5.5"

1. Title must be in all upper case (capital) letters, authors' full names and text in upper and lower case.
2. Follow title with all authors' names including credentials (underline presenter's name), institution, and location.
3. Do not justify (ie, leave a 'ragged' right margin).
4. **Do not use type size less than 10 points.**
5. All text and the table, or figure, must fit into the rectangle shown. (Use only 1 clear, concise table or figure.)
6. Submit 2 clean copies.

Mail original & 1 photocopy (along with postage-paid postcard) to

2000 RESPIRATORY CARE OPEN FORUM
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Manuscript Preparation Guide

General Information

RESPIRATORY CARE welcomes original manuscripts related to the science and technology of respiratory care and prepared according to these Instructions and the *Uniform Requirements for Manuscripts Submitted to Biomedical Journals* [Respir Care 1997; 42(6):623-634]. Manuscripts are blinded and reviewed by professionals who are experts in their fields. Authors are responsible for all aspects of the manuscript and receive galleys to proofread before publication. Each accepted manuscript is copyedited so that its message is clear and it conforms to the Journal's style. Published papers are copyrighted by Daedalus Inc and may not be published elsewhere without permission.

Editorial consultation is available at any stage of planning or writing. On request, specific guidance is provided for all publication categories. To receive these Instructions and related materials, write to RESPIRATORY CARE, 600 Ninth Avenue, Suite 702, Seattle WA 98104, call (206) 223-0558, or fax (206) 223-0563.

Publication Categories & Structure

Research Article: A report of an original investigation (a study). It includes a Title Page, Abstract, Introduction, Methods, Results, Discussion, Conclusions, Product Sources, Acknowledgments, References, Tables, Appendices, Figures, and Figure Captions.

Evaluation of Device/Method/Technique: A description and evaluation of an old or new device, method, technique, or modification. It has a Title Page, Abstract, Introduction, Description of Device/Method/Technique, Evaluation Methods, Evaluation Results, Discussion, Conclusions, Product Sources, Acknowledgments, References, Tables, Appendices, Figures, and Figure Captions. Comparative cost data should be included wherever possible.

Case Report: A report of a clinical case that is uncommon, or was managed in a new way, or is exceptionally instructive. All authors must be associated with the case. A case-managing physician must either be an author or furnish a letter approving the manuscript. Its components are Title Page, Abstract, Introduction, Case Summary, Discussion, References, Tables, Figures, and Figure Captions.

Review Article: A comprehensive, critical review of the literature and state-of-the-art summary of a pertinent topic that has been the subject of at least 40 published research articles. Title Page, Outline, Introduction, Review of the Literature, Summary, Acknowledgments, References. Tables, Appendices, and Figures and Captions may be included.

Overview: A critical review of a pertinent topic that has fewer than 40 published research articles.

Update: A report of subsequent developments in a topic that has been critically reviewed in this Journal or elsewhere.

Point-of-View Paper: A paper expressing personal but substantiated opinions on a pertinent topic. Title Page, Text, References, Tables, and Illustrations may be included.

Special Article: A pertinent paper not fitting one of the foregoing categories may be acceptable as a Special Article. Consult with the Editor before writing or submitting such a paper.

Editorial: A paper drawing attention to a pertinent concern; it may present an opposing opinion, clarify a position, or bring a problem into focus.

Letter: A signed communication, marked "For publication," about prior publications in this Journal or about other pertinent topics. Tables and illustrations may be included.

Blood Gas Corner: A brief, instructive case report involving blood gas values—with Questions, Answers, and Discussion.

Drug Capsule: A mini-review paper about a drug or class of drugs that includes discussions of pharmacology, pharmacokinetics, and pharmacotherapy.

Graphics Corner: A brief case report incorporating waveforms for monitoring or diagnosis—with Questions, Answers, and Discussion.

Kittredge's Corner: A brief description of the operation of respiratory care equipment—with information from manufacturers and editorial comments and suggestions.

PFT Corner: Like Blood Gas Corner, but involving pulmonary function tests.

Cardiorespiratory Interactions. A case report demonstrating the interaction between the cardiovascular and respiratory systems. It should be a patient-care scenario; however, the case—the central theme—is the systems interaction. CRI is characterized by figures, equations, and a glossary. See the March 1996 Issue of RESPIRATORY CARE for more detail.

Test Your Radiologic Skill: Like Blood Gas Corner, but involving pulmonary medicine radiography and including one or more radiographs; may involve imaging techniques other than conventional chest radiography.

Review of Book, Film, Tape, or Software: A balanced, critical review of a recent release.

Preparing the Manuscript

Print on one side of white bond paper, 8.5 in. x 11 in. (216 x 279 mm) with margins of at least 1 in. (25 mm) on all sides of the page. Use ***double-spacing*** throughout the ***entire*** manuscript. Use a standard font (eg, Times, Helvetica, or Courier) at least 10 points in size, and

do not use italics except for special emphasis. Number all pages in upper-right corners. Indent paragraphs 5 spaces. Do ***not justify***. **Do *not* put authors' names, institutional affiliations or allusions to institutional affiliations in the text, or other identification anywhere except on the title page.** Repeat title only (no authors) on the abstract page. Begin each of the following on a new page: Title Page, Abstract, Text, Product Sources List, Acknowledgments, References, each Table, and each Appendix. Use standard English in the first person and active voice.

Center main section headings on the page and type them in capital and small letters (eg, Introduction, Methods, Results, Discussion). Begin subheadings at the left margin and type them in capital and small letters (eg, Patients, Equipment, Statistical Analysis).

References. Cite only published works as references. Manuscripts accepted but not yet published may be cited as references: designate the accepting journal, followed by (in press), and provide 3 copies of the in-press article for reviewer inspection. Cite references in the text with superscript numerals. Assign numbers in the order that references are first cited. On the reference page, list the cited works in numerical order. Follow the Journal's style for references. Abbreviate journal names as in *Index Medicus*. List all authors.

Article in a journal carrying pagination throughout volume:

> Rau JL, Harwood RJ. Comparison of nebulizer delivery methods through a neonatal endotracheal tube: a bench study. Respir Care 1992;37(11):1233-1240.

Article in a publication that numbers each issue beginning with Page 1:

> Bunch D. Establishing a national database for home care. AARC Times 1991;15(Mar):61,62,64.

Corporate author journal article:

> American Association for Respiratory Care. Criteria for establishing units for chronic ventilator-dependent patients in hospitals. Respir Care 1988;33(11):1044-1046.

Article in journal supplement: (Journals differ in their methods of numbering and identifying supplements. Supply sufficient information to promote retrieval.)

> Reynolds HY. Idiopathic interstitial pulmonary fibrosis. Chest 1986; 89(3 Suppl):139S-143S.

Abstract in journal: (Abstracts citations are to be avoided. Those more than 3 years old should not be cited.)

> Stevens DP. Scavenging ribavirin from an oxygen hood to reduce environmental exposure (abstract). Respir Care 1990;35(11): 1087-1088.

Editorial in journal:

> Enright P. Can we relax during spirometry? (editorial). Am Rev Respir Dis 1993;148(2):274.

Editorial with no author given:

> Negative-pressure ventilation for chronic obstructive pulmonary disease (editorial). Lancet 1992;340(8833):1440-1441.

Letter in journal:

> Aelony Y. Ethnic norms for pulmonary function tests (letter). Chest 1991;99(4):1051.

Paper accepted but not yet published:

> Hess D. New therapies for asthma. Respir Care (year, in press).

Personal author book: (For any book, specific pages should be cited whenever possible.)

> DeRemee RA. Clinical profiles of diffuse interstitial pulmonary disease. New York: Futura; 1990. p. 76-85.

Corporate author book:

> American Medical Association Department of Drugs. AMA drug evaluations, 3rd ed. Littleton CO: Publishing Sciences Group; 1977.

Chapter in book with editor(s):

> Pierce AK. Acute respiratory failure. In: Guenter CA, Welch MH, editors. Pulmonary medicine. Philadelphia: JB Lippincott; 1977:26-42.

Tables. Use consecutively numbered tables to display information. Start each table on a separate page. Number and title the table and give each column a brief heading. Place explanations in footnotes, including all nonstandard abbreviations and symbols. Key the footnotes with conventional designations (*, †, ‡, §, ‖, ¶, **, ††) in consistent order, placing them superscript in the table body. Do not use horizontal or vertical rules or borders. Do not submit tables as photographs, reduced in size, or on oversize paper. Use the same typeface as in the text.

Illustrations. Graphs, line drawings, photographs, and radiographs are figures. Use only illustrations that clarify and augment the text. Number them consecutively as Fig. 1, Fig. 2, and so forth according to the order by which they are mentioned in the text. Be sure all figures are cited. If any figure was previously published, include copyright holder's written permission to reproduce. Figures for publication must be of professional quality. Data for the original graphs should be available to the Editor upon request. If color is essential, consult the Editor for more information. In reports of animal experiments, use schematic drawings, not photographs. A letter of consent must accompany any photograph of a person. Do not place titles and detailed explanations on figures; put this information in figure captions. If possible, submit radiographs as prints and full-size copies of film.

Drugs. Identify precisely all drugs and chemicals used, giving generic names, doses, and routes of administration. If desired, brand names may be given in parentheses after generic names. Drugs should be listed on the product-sources page.

Commercial Products. In parentheses in the text, identify any commercial product (including model number if applicable) the first time it is mentioned, giving the manufacturer's name, city, and state or country. If four or more products are mentioned, do not list any manufacturers in the text; instead, list them on a Product Sources page at the end of the text, before the References. Provide model numbers when available and manufacturer's suggested price, if the study has cost implications.

Ethics. When reporting experiments on human subjects, indicate that procedures were conducted in accordance with the ethical standards of the *World Medical Association Declaration of Helsinki* [Respir Care 1997;42(6):635-636] or of the institution's committee

on human experimentation. State that informed consent was obtained. Do not use patient's names, initials, or hospital numbers in text or illustrations. When reporting experiments on animals, indicate that the institution's policy, a national guideline, or a law on the care and use of laboratory animals was followed.

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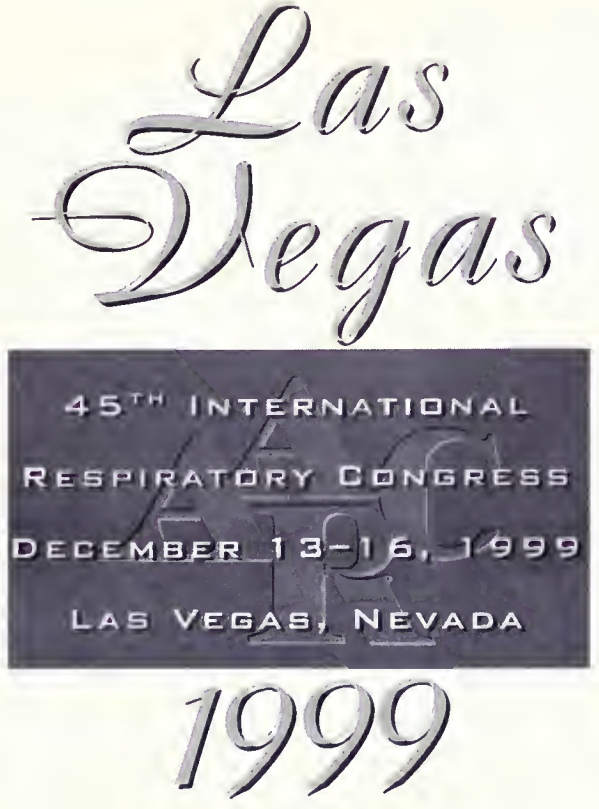

Authors in This Issue

Becker, Ellen A 1337
Branson, Richard D 1388
Chatburn, Robert L 1391
Dhand, Rajiv 1353
Durmowicz, Anthony G 1390
Fink, James 1353
Gibson, Chère C 1337
Gilman, Georges 1388
Goldberg, Stefan 1392
Hashimoto, Shu 1375
Hayashi, Shinichi 1375
Horie, Takashi 1375
Khoo, Michael CK 1390
Mishoe, Shelley C 1332
Tonelli, Mark R 1383

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Branson, Richard D 1388
Chatburn, Robert L 1391
Dhand, Rajiv 1353
Durmowicz, Anthony G 1390
Fink, James 1353
Gibson, Chère C 1337
Gilman, Georges 1388
Goldberg, Stefan 1392
Hashimoto, Shu 1375
Hayashi, Shinichi 1375
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